PRESETTLEMENT VEGETATION OF PART OF NORTHWESTERN MOFFAT COUNTY, COLORADO, DESCRIBED FROM REMNANTS

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ABSTRACT.—A general botanical inventory of a part of northwestern Moffat County, Colorado, resulted in the location of "remnants" of the presettlement vegetation spectrum that are largely unaltered by grazing, logging, or other recent human-related land uses. The 69 samples taken from these remnants were classified into 22 plant associations. Composition, structure, environmental location, geographical range, and response to disturbance are discussed for each association, and a photograph of each is presented. Seven of the 22 associations are apparently restricted to the study area. Restricted associations occur in the more extreme environments of the study area, such as on calcareous substrata or very xeric sites. More mesic sites along ephemeral creeks, on north-facing slopes, or on sandstones support plant associations that have much wider ranges, many of them extending across the northern Great Basin.

The vegetation that occupied the landscape in the western United States prior to settlement has been effectively extirpated in some areas by conversion to cultivation or by urban development. In most of the remainder, other kinds of land use have resulted in alteration of the presettlement composition and structure. The most pervasive and most consequential of these other land uses are domestic livestock grazing and logging, though mining and recreation have had substantial effects in more localized areas. Also pervasive has been the replacement of native plant species by exotics. Additional effects have resulted from fire control, loss or modification of native herbivore populations, exotic diseases, air pollution, and acid precipitation. In some parts of the western United States, and in many parts of the eastern United States, the composition and structure of the presettlement vegetation can only be known now by reference to historical accounts, early photographs, and other secondary records. Vale (1982) reviewed methods of analyzing these sources. Nevertheless, in parts of the West it is still possible to locate remnants of the presettlement vegetation, which have essentially escaped alteration, though such remnants are exceedingly rare at lower elevations or on very productive sites and are disappearing as land uses continue or accelerate.

These remnants have been widely used in the forested parts of the western United States to develop "habitat type" classifications (Pfister 1982). Such classifications are irreplaceable records of the detailed composition and structure of the presettlement vegetation. Some of these remnants, occurring on federal lands, have been protected from further alteration or loss by designation as Research Natural Areas under regulations and policies of the U.S. Department of the Interior, Department of Agriculture, and other departments. Perpetuation of remnants in such designated Research Natural Areas means that they will be available in the future for more extensive study. Very few opportunities are available for the study of ecosystem function on unaltered sites. Without such studies it is difficult for land managers to know how to most efficiently manage land uses on similar lands for maximum benefit with minimum alteration. Such protected remnants also serve an important role in the long-term perpetuation of their component plants and animals.

The natural vegetation of some parts of Colorado is nearly unknown (Baker 1982a), particularly at lower elevations. An earlier report characterized some of the presettlement vegetation of the Piceance Basin occurring on Green River and Uinta formations (Baker 1983). This report extends that earlier report to include additional areas of Green River Formation (Fm.) and other geologic substrata occurring in a part of northwestern Moffat

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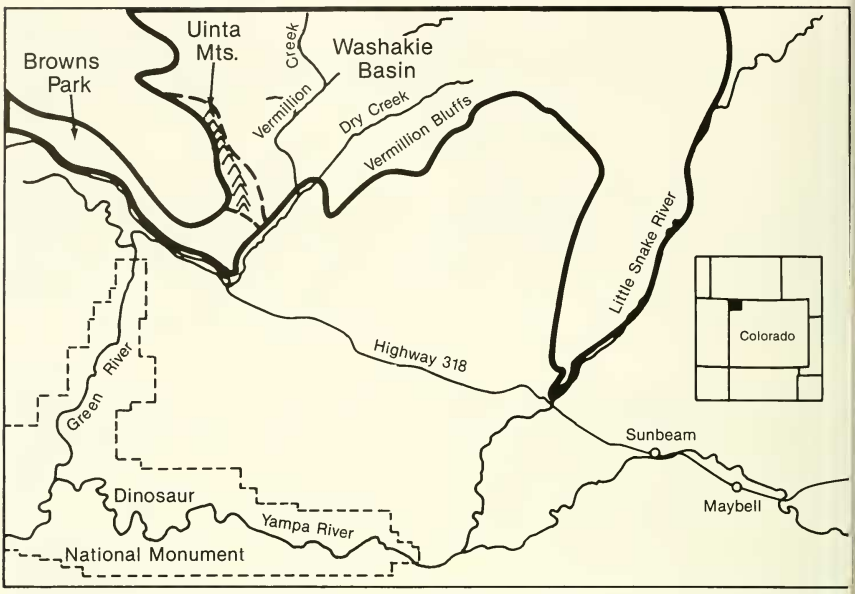

Fig. 1. Map of the study area.

County, Colorado (Fig. 1), again based on remnants located during a general botanical inventory (Peterson and Baker 1983) of this area.

STUDY AREA

The study area (Fig. 1) includes part of northwestern Moffat County north of Highway 318 and west of the Little Snake River. Excluded from study within this area are the Sand Wash Basin and the forested summits of Cold Spring Mountain, Middle Mountain, and Diamond Peak. The study area includes parts of Browns Park, the eastern Uinta Mountains, and the Washakie Basin. Concentrated study was made of the Limestone Ridge, Vermillion–Dry Creeks, and Vermillion Bluffs area. Elevations in the study area range from about 1830 to 2600 m.

The stratigraphy of exposed rocks in the study area is complex. The most comprehensive geologic map is Rowley et al. (1979). Additional mapping is available in Sears (1924), Nightingale (1930), and Bradley (1964). In the Uinta Mountains section of the study area, exposures of pre-Tertiary rocks predominate. These consist primarily of sandstones (Mesa Verde Group, Dakota, Entrada, Glen Canyon, Weber, Morgan, Lodore formations) and shales and siltstones (Mancos, Morrison, Chinle, Moenkopi formations), though Limestone Ridge is capped by Madison limestone and other minor beds in the above formations may contain limestone. In the Washakie Basin section of the study area, Eocene rocks of the Green River Formation and Wasatch Formation predominate (Bradley 1964), though along the base of the Uintas and throughout Browns Park the Browns Park Formation is common, and localized Quaternary alluvial and colluvial deposits may occur. The Green River Formation in this area consists of two members (Wilkins Peak, Laney), and two tongues (Tipton, Luman). The Wilkins Peak Member, consisting of a sequence of thin beds of marlstone, mudstone, and oil shale, is composed of a greater abundance of saline minerals and dolomite than any other beds in the Green River Formation (Bradley 1964). The Laney Member is muddy marlstone and brown to light ash gray shale. The Tipton

Tongue consists of sandstone beds and beds of greenish gray shale and gray mudstone. The Luman Tongue consists of shell marl, sandstone, and conglomerate. The Wasatch Formation occurs as the main body, consisting primarily of fluviatile sandy mudstone, and two tongues (Niland, Cathedral Bluffs). The Niland Tongue consists of mudstone, shale, and lenticular tuff, and the Cathedral Bluffs Tongue consists of pink and red-layered gray mudstone that forms badland slopes (Bradley 1964). The Miocene Browns Park Formation consists primarily of soft, well-bedded chalk-white sandstone (Nightingale 1930), though there are local beds of tuff, limestone, and volcanic materials (Rowley et al. 1979).

Climatic data are available from Craig, Colorado (Gale Research Co. 1980), about 50 km southeast of the study area, at about the same elevation as the lowest elevations in the study area. Mean annual precipitation there is 338 mm, distributed fairly evenly throughout the year. Mean January temperature is −7.7 C, with mean July temperature 19.4 C.

There have been no studies or general descriptions of vegetation in the study area. Though Lindauer et al. (1982) reviewed the literature on the broad area of northwestern Colorado and discussed some general vegetation types, their study was not concerned with presettlement conditions. In adjoining Utah, Woodbury et al. (1960) sampled vegetation in the Flaming Gorge area but did not present a classification, presented minimal understory data, and did not attempt to characterize presettlement conditions. Svihla (1932) described vegetation zones in the Uinta Mountains, recognizing a sagebrush zone from 1765 to 2745 m, a cedar-pinyon minor belt from 2130 to 2440 m, and several zones above these. Graham (1937), in his study of the Uinta Basin, revised Uinta Mountain zonation to include a mixed desert shrub zone from 1370 to 1675 m, a juniper-pinyon zone from 1675 to 2130 m, a submontane shrub zone from 2130 to 2440 m, and several zones above these. In the Uinta Mountain portion of the study area, Graham's zonation scheme requires modification. The mixed desert shrub zone occurs up to or occasionally above about 1825 m, the juniper-pinyon zone extends from 1825 to 2375 m, and above this elevation the submontane shrub zone extends to about 2560 m. In the adjoining Washakie Basin part of the study area, this zonation scheme does not accurately describe vegetation patterns. Most elevations in this area are between 1980 and 2285 m. In this elevational band, plant associations dominated by saltbushes and sagebrush occur in a mosaic. Juniper occurs only in a few areas on steep slopes or above 2130 m.

Methods

Field Methods

Remnants of natural vegetation occur on sites that either have not been grazed by domestic livestock or have been grazed lightly, have not been logged, mined, cultivated, or subjected to other surface disturbances, and are free of obvious effects of fire control, acid rain, air pollution, or other postsettlement human-related disturbances. In an area such as the study area, where the predominant current land use is domestic livestock grazing, remnants are most often found in areas removed from water, or on steep slopes, or in areas that have escaped heavy use because of accidents of fencing or use patterns. Cattle and sheep eat primarily grass and forbs in addition to some of the more edible shrubs, so that effects of grazing are often most pronounced in the understory of most vegetation types in the study area. Decline in understory density can result in an increase in shrub or overstory density over time. Domestic livestock also alter vegetation by trampling, which results in breakage of shrub stems and changes in soil surface morphology. A soil surface layer dominated by cryptogams is well known to disappear under the effects of trampling by domestic livestock (Anderson et al. 1982a, 1982b). Methods of locating and identifying remnants, using these and other criteria, are described in detail in Baker (1982b, 1983) and Daubenmire (1970).

Located remnants were sampled quantitatively using a temporary 375 m^2 circular plot method. This method has been widely utilized in the western United States for habitat typing (e.g., Pfister et al. 1977). Within the plot, canopy coverage of all vascular plant species was estimated to the nearest 1% (below 15%) or 5% (above 15%). Species with less

than .5% cover were recorded as having trace cover (abbreviated "tr" in the tables). Tree species within the plot were tallied by 2 in dbh size classes. Seedlings are considered to be those individuals less than 1 m tall and less than 1 in dbh; saplings are greater than 1 m tall and less than 1 in dbh. Diameter at breast height (dbh) was in actual practice measured below the major point of branching on *Juniperus* and *Pinus* stems, as these trees often lack a single stem at actual breast height.

Reported responses to domestic livestock grazing were derived by examining fenceline contrasts and by comparing located remnants with areas currently being grazed at various levels. These observations were compared with those reported in the scientific literature for similar vegetation.

Soils

Soil samples from the upper 15 cm of the profile were taken from near the center of the sampling plot, air-dried in the field, and removed to the laboratory for analysis. All samples were passed through a 2-mm sieve (Richards 1954) prior to analysis. Electrical conductivity (soluble salts) and pH values were determined according to methods described by Soltanpour and Workman (1981). An Orion Model 21 Digital pH meter and probe were used to obtain readings from each saturated soil paste. A Lab-Line Lectro Mho-Conductivity Meter (Model Mc-1, Mark IV) was used to obtain electrical conductivity values (millimhos/cm) of saturation extracts at 25 C.

Nomenclature

The plant associations named here follow the vegetation nomenclature detailed in Baker (1984). Plant species nomenclature follows Kartesz and Kartesz (1980). Questionable plant specimens were identified by Dr. Dieter Wilken, curator of the herbarium, Colorado State University. Certain taxonomic separations were found to be difficult to apply consistently during field sampling. *Gilia sinuata* may include some other annual *Gilia* species. *Agropyron smithii* may occasionally include *Agropyron dasystachyum*. *Opuntia polyacantha* may include other *Opuntia* species. The common low-growing *Atriplex* in the study area may in some populations consist of a mixture of specimens of both *Atriplex cuneata* and *Atriplex gardneri* (Wilken, personal communication), with some indication of possibly intermediate individuals. The complex is here called by the name *Atriplex gardneri*.

Natural Vegetation Concept

Natural vegetation is that vegetation that existed prior to the changes that have accompanied European settlement, essentially the presettlement vegetation. This concept is similar in many respects to the habitat type concept pioneered by Daubenmire (1952, 1970) and now widely used in the western United States (e.g., Pfister et al. 1977). The differences between this concept and Daubenmire's are discussed in detail in Baker (1984).

It is important to recognize that the remnants located represent, as well as is still possible within the study area, the composition and structure of the presettlement vegetation. Most of these remnants, however, now contain a minor component of exotic plant species that was not present in the association prior to settlement. The actual presettlement composition must be inferred to some degree, perhaps by subtracting these exotic species and increasing slightly the coverage of native species. In some instances an individual stand may lack species it contained prior to settlement, because of either natural population fluctuations or loss from postsettlement land uses that have left no other lasting evidence within the stand.

Results and Discussion

Plant Associations

1. *Juniperus osteosperma/Agropyron spicatum*. —This association occurs on any aspect, and on several parent materials (Green River Fm.–Laney Member, Madison Limestone, Weber Sandstone, and others) from 1920 to 2250 m in elevation often on steep slopes, but also on flats. Soils, which are moderately well developed but may be very rocky, have an average pH of 7.79 and an electrical conductivity of .48 mmhos/cm (Table 1).

The association has a savanna appearance (Fig. 2), with the shrub layer generally nearly

TABLE 1. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 1 = *Juniperus osteosperma/Agropyron spicatum*, 2 = *Juniperus osteosperma–Pinus edulis/Artemisia nova/Agropyron spicatum*, 3 = *Juniperus osteosperma–Pinus edulis/Cercocarpus ledifolius* var. *intricatus*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover for all the plots in the association on the left of the slash and percent constancy to the right of the slash. 100% is abbreviated to 99. Soil EC is soil electrical conductivity; its measurement is discussed in the text.

Township	10 N	10 N	10 N	10 N		10 N	11 N		10 N	10 N	10 N	10 N	
Range	101W	101W	99W	100W		101W	101W		101W	101W	101W	100W	
Section	S23	S15	S9	S27		S34	S32		S15	S14	S25	S30	
Elevation (meters)	2060	2160	2170	2080		1890	2290		2190	2070	1890	1900	
Aspect	SW	E	NE	S		W	SE		W	NE	W	E	
Slope (degrees)	30	20	15	5		20	20		10	5	5	10	
Soil pH	7.95	7.85	7.70	7.65	Avg = 7.79	7.75	7.95	Avg = 7.85	8.15	7.90	7.65	8.00	Avg = 7.93
Soil EC (mmhos/cm)	.37	.86	.33	.36	Avg = .48	.34	.34	Avg = .34	27	.34	.40	.29	Avg = .33
Plant association number	1					2			3				
Plot number	1	2	3	4	Cov/Con	1	2	Cov/Con	1	2	3	4	Cov/Con
SHRUBS													
Ephedra viridis	2	tr			.6/50				1	tr			tr/50
Artemisia tridentata ssp. *wyomingensis*		tr	tr		tr/50								
Atriplex confertifolia			tr		tr/25								
Opuntia polyacantha				tr	tr/25						tr		tr/25
Pediocactus simpsonii				tr	tr/25								
Artemisia nova						10	8	9.0/99			tr	2	.6/50
Cercocarpus montanus							tr	tr/50					
Symphoricarpos oreophilus							tr	tr/50					
Cercocarpus ledifolius var. *intricatus*									22	15	15	10	15.5/99
Chrysothamnus nauseosus									tr	tr	tr	tr	tr/99
Chrysothamnus viscidiflorus									tr				tr/25
Fendlerella utahensis									tr				tr/25
Purshia tridentata										tr			tr/25
GRAMINOIDS													
Agropyron spicatum	25	20	20	20	21.3/99	10	17	13.5/99				tr	tr/25
Poa sandbergii	2		1	1	1.0/99		3	1.5/50	tr	tr	tr	tr	tr/99
Poa fendleriana	2	3	7	1	3.3/99								
Oryzopsis hymenoides	tr	tr	tr		tr/75	tr	1	.8/99	tr	tr	tr		tr/75
Bromus tectorum	tr	2			.6/50	tr	2	1.3/99	tr			tr	tr/50
Sitanion hystrix		tr			tr/25		tr	tr/50					
Koeleria cristata			1		tr/25		2	1.0/50					
Poa canbyi			tr		tr/25								
Carex filifolia				tr	tr/25						1	2	.8/50
Carex pityophila							tr	tr/50	2				tr/25
FORBS													
Physaria acutifolia	tr	tr		tr	tr/75	1	1	1.0/99		tr		tr	tr/50
Cryptantha flavoculata	tr	tr	1	tr	.6/99		1	tr/50					
Erigeron sp.	tr				tr/25								
Descurainia richardsonii	tr	tr	1	tr	.6/99	1	tr	.8/99	tr	tr	1	tr	.6/99
Phlox hoodii	1		1	1	.8/75	1		tr/50		tr	1	tr	tr/75
Hedeoma drummondii	tr				tr/25								
Gilia sinuata	tr	tr			tr/50							tr	tr/25
Eriogonum ovalifolium	tr		tr	tr	tr/75								
Caulanthus crassicaulis		tr		tr	tr/50	tr	tr	tr/99				tr	tr/25
Conringia orientalis		tr			tr/25								
Agoseris glauca		tr			tr/25		tr	tr/50					
Arabis demissa		tr	tr	tr	tr/75	tr	tr	tr/99	tr	tr		tr	tr/75
Schoenocrambe linifolia		tr		tr	tr/50		tr	tr/50					
Balsamorhiza hookeri var. *hispidula*		tr	3	1	1.1/75		2	1.0/50					
Mertensia oblongifolia		tr	2		.6/50		1	tr/50					
Crepis occidentalis		tr	tr		tr/50								
Senecio integerrimus		tr			tr/25								
Haplopappus acaulis		tr	1	tr	tr/75	1	3	2.0/99	tr				tr/25
Cryptantha fendleri		tr		1	tr/50		tr	tr/50					
Lappula redowskii		tr		tr	tr/50								
Phlox longifolia			tr		tr/25								
Astragalus tenellus			2		tr/25								
Trifolium gymnocarpon			tr		tr/25								
Astragalus convallarius			1	tr	tr/50								
Arenaria fendleri			tr		tr/25								
Eriogonum umbellatum			1		tr/25		tr	tr/50					
Erigeron eatonii			tr		tr/25								
Penstemon fremontii			tr	tr	tr/50		tr	tr/50				tr	tr/25
Cryptantha sericea			tr		tr/25								
Castilleja chromosa			tr		tr/25								
Chaenactis douglasii			tr		tr/25								

Table 1 continued.

Township	10 N	10 N	10 N	10 N			10 N	11 N			10 N	10 N	10 N	10 N		
Range	101W	101W	99W	100W			101W	101W			101W	101W	101W	100W		
Section	S23	S15	S9	S27			S34	S32			S15	S14	S25	S30		
Elevation (meters)	2060	2160	2170	2080			1890	2290			2190	2070	1890	1900		
Aspect	SW	E	NE	S			W	SE			W	NE	W	E		
Slope (degrees)	30	20	15	5			20	20			10	5	5	10		
Soil pH	7.95	7.85	7.70	7.65	Avg	7.79	7.75	7.95	Avg	7.85	8.15	7.90	7.65	8.00	Avg	7.93
Soil EC (mmhos/cm)	.37	.86	.33	.36	Avg	.48	.34	.34	Avg	.34	.27	.34	.40	.29	Avg	.33
Plant association number	1						2				3					
Plot number	1	2	3	4		Cov/Con	1	2		Cov/Con	1	2	3	4		Cov/Con
Astragalus detritalis			tr			tr/25										
Eriogonum sp.				tr		tr/25	tr			tr/50				tr		tr/25
Ipomopsis congesta				tr		tr/25										
Lupinus brevicaulis				tr		tr/25										
Haplopappus armerioides				tr		tr/25										
Atriplex sp.				tr		tr/25										
Hymenoxys acaulis							tr			tr/50						
Trifolium longipes ssp. *pygmaeum*							2			1.0/50						
Eriogonum tumulosum							tr			tr/50			1			tr/25
Lesquerella alpina							tr			tr/50						
Penstemon yampaensis							tr			tr/50						
Machaeranthera grindeloides							tr			tr/50						
Cymopterus sp.								tr		tr/50						
Petradoria pumila								1		tr/50						
Calochortus nuttallii								tr		tr/50						
Erigeron flagellaris								tr		tr/50						
Petrophytum caespitosum											3					.8/25
Cryptantha sp.											1					tr/25
Erigeron nematophyllus												tr	tr			tr/50
Astragalus spatulatus													2	1		.8/50
Cryptantha flava												tr				tr/25
Erysimum asperum													tr	tr		tr/50
Cryptantha caespitosa													tr			tr/25
Arabis pulchra													tr			tr/25
Oxytropis sericea													tr	tr		tr/50
Stanleya pinnata														tr		tr/25
Vicia americana														tr		tr/25
Nemophila breviflora														tr		tr/25
Cymopterus fendleri														tr		tr/25
Lesquerella ludoviciana														tr		tr/25
Arenaria fendleri														tr		tr/25
Lappula redowskii														tr		tr/25

absent. *Agropyron spicatum* forms a dense sward in stands that are in good condition (Table 1). Stands usually consist of a moderately dense (320—510 trees/ha) overstory of pure *Juniperus osteosperma* (Table 2). *Pinus edulis*, when present, consists primarily of seedlings, but an occasional larger stem may occur. Many stands consist of only large stems (9–35 in dbh), with very few smaller stems or seedlings and saplings.

Domestic livestock grazing results in decreases in *Agropyron spicatum* and *Poa fendleriana* and increases in shrubs, herbs, and the exotic grass *Bromus tectorum*. Several stands were observed with *Poa sandbergii* dominant and only trace quantities of *Agropyron spicatum* remaining. Another grazing-induced successional stage has *Artemisia tridentata* ssp. *wyomingensis* dominant in the understory, with only small amounts of grass present. On very flat sites *Haplopappus acaulis* may become very abundant.

This association is limited in Colorado to northern and western Moffat County. It has been observed in Utah in Dinosaur National Monument (Welsh 1957) and in western Wyoming (DeSpain 1973, Wight and Fisser 1968). In the study area it is the most common pinyon-juniper woodland, though a large percentage of stands have been altered by domestic grazing or by woodcutting.

2. *Juniperus osteosperma–Pinus edulis/Artemisia nova/Agropyron spicatum.* —This association occurs on a variety of aspects on several parent materials (e.g., Browns Park Fm., Morgan Fm.) on steep slopes (15–25 degrees) from 1830 to 2375 m in elevation. Soils are similar to those of the *Juniperus osteosperma/Agropyron spicatum* association, having an average pH of 7.85 and an electrical conductivity of .34 mmhos/cm (Table 1).

It consists of a moderately dense (400–500 trees/ha) stand of *Juniperus osteosperma* and *Pinus edulis* (Table 2, Fig. 2). *Juniperus* stems

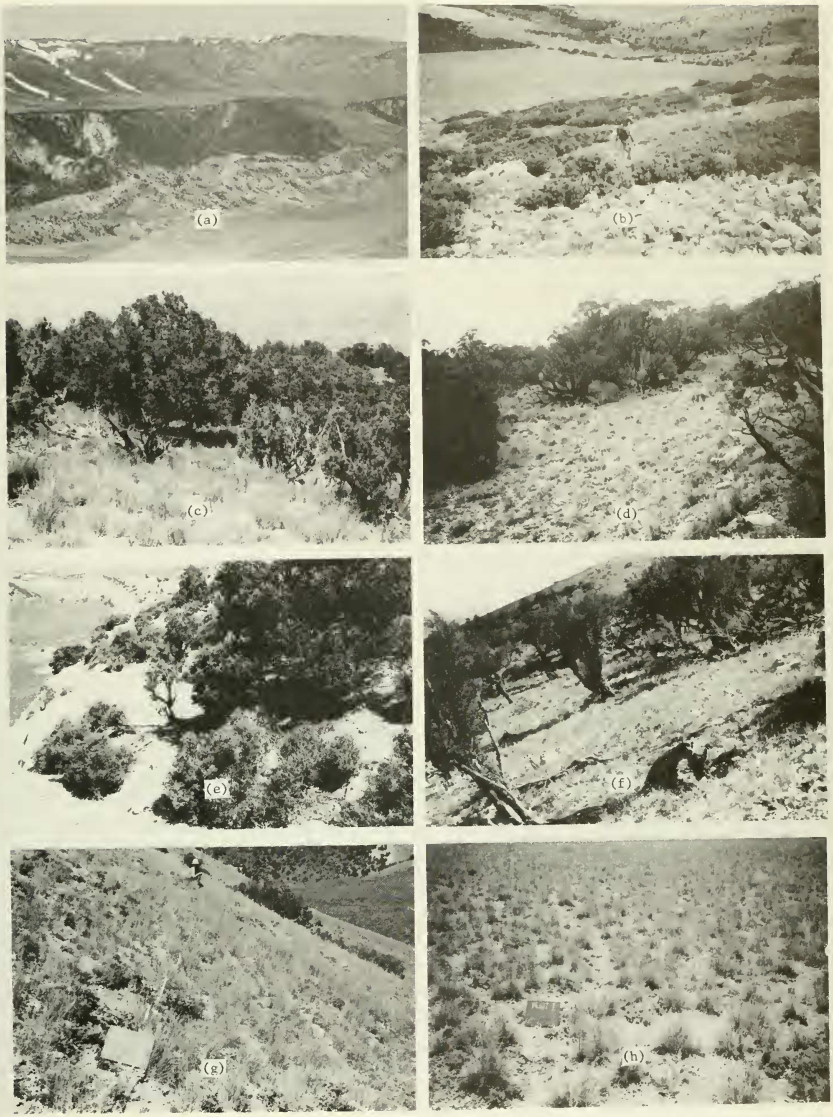

Fig. 2. (a) Limestone Ridge and part of the study area, (b) *Juniperus osteosperma* "krummholz," (c) *Juniperus osteosperma/Agropyron spicatum*, (d) *Juniperus osteosperma–Pinus edulis/Artemisia nova/Agropyron spicatum*, (e) *Juniperus osteosperma–Pinus edulis/Cercocarpus ledifolius* var. *intricatus*, (f) *Cercocarpus ledifolius/Artemisia tridentata* ssp. *wyomingensis–Symphoricarpos oreophilus/Agropyron spicatum*, (g) *Artemisia nova/Agropyron spicatum*, (h) *Artemisia nova/Stipa comata*.

TABLE 2. Tree diameter size distribution. Tree diameters were measured by 2" size class at breast height (dbh). Seedlings are less than 1" dbh and less than 1 m tall. Saplings are less than 1" dbh and greater than 1 m tall. Size classes are listed by the midpoint of the size class. Entries are the number of stems in each size class within the 375 m^2 plot.

Plot No.	Species	Seedlings	Saplings	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	31+
Juniperus osteosperma/Agropyron spicatum																			
1	*Juniperus osteosperma*	2	1	1	1	1	4	1	1	1	1								
	Pinus edulis	5	1					1											
2	*Juniperus osteosperma*	3						3		4	2		1		1			2	
	Pinus edulis	8						1	1										
3	*Juniperus osteosperma*	1		3	3			1		1	1	1	2	1	1	1		1	3 (34,35,35)
4	*Juniperus osteosperma*							1	1	1	2		3	2	1	1			
Juniperus osteosperma–Pinus edulis/Artemisia nova/Agropyron spicatum																			
1	*Juniperus osteosperma*	8		2	2	1		1		1		1	1	1	1	1			
	Pinus edulis	10	3	4		1													
2	*Juniperus osteosperma*	4	1	1	1	1	1	2		1			2	1			1		1 (35)
	Pinus edulis	2	2	4			1												
Juniperus osteosperma–Pinus edulis/Cercocarpus ledifolius var. *intricatus*																			
1	*Juniperus osteosperma*	3	1	3	2		2		1										
	Pinus edulis	4	5	4	3	4	1	1											
2	*Juniperus osteosperma*			1			1	1	1		1								
	Pinus edulis		1	1		4	2	4		1									
3	*Juniperus osteosperma*	2	3					1	1		1				1		1		1 (35)
	Pinus edulis					1	2	3	1										
4	*Juniperus osteosperma*			1	1		1	1			2	1	1						
	Pinus edulis	2	1		2	1													
Cercocarpus ledifolius/Artemisia tridentata ssp. *wyomingensis–Symphoricarpos oreophilus/Agropyron spicatum*																			
1	*Cercocarpus ledifolius*	5	1	1		1	1	1		1	1						1		1 (34)
	Juniperus scopulorum		2																
	Pinus edulis	1																	
2	*Cercocarpus ledifolius*	16	1		1	1	2	2		2	2							1	
	Juniperus scopulorum			1															
	Pinus edulis		2																
3	*Cercocarpus ledifolius*	14	7	8	7	5													
	Juniperus scopulorum	1	2							1									
	Pinus edulis	1																	

may be more abundant and often larger than *Pinus* stems. Both species typically have abundant small stems. The shrub layer is sparse (Table 1), with 8%–10% cover of *Artemisia nova*, which may be nearly hidden by dense *Agropyron spicatum* (Fig. 2).

Domestic livestock grazing results in an increase in *Poa sandbergii*, *Haplopappus acaulis*, *Balsamorhiza hookeri* var. *hispidula*, and the exotic *Bromus tectorum*. *Agropyron spicatum* may decrease and is often nearly absent on heavily grazed sites. *Artemisia nova* does not appear to increase appreciably.

This association was first located in Colorado during this study. It occurs within the study area in only two locations near Limestone Ridge. Data collected in Dinosaur National Monument suggest it may also occur there (S. Wathen, personal communication). It is probably limited in Colorado to northwestern Moffat County but has been reported from southeastern Idaho about 600 km northwest of the study area (Johnson and Pfister 1982), and probably occurs in the intervening areas in southwestern Wyoming and northeastern Utah.

3. *Juniperus osteosperma–Pinus edulis/Cercocarpus ledifolius* var. *intricatus*.—This association is found exclusively on sandstone outcrops of several formations (Weber Sandstone, Glen Canyon Sandstone, Entrada Sandstone, and Mesa Verde Group Sandstone) in the study area, typically occurring on rocky ridge tops or abrupt sandstone outcrops where bedrock is extensively exposed and somewhat cracked and jointed. Aspects are variable, slopes range from 0° to 30°, and the association may occur from 1825 to 2300 m in elevation. Soils are poorly developed, but where there is soil it is similar in average pH (7.93) and electrical conductivity (.33 mmhos/cm) to that of the other pinyon-juniper associations in the study area (Table 1).

The association consists of a moderately dense (290–560 trees/ha) stand of *Juniperus osteosperma* and *Pinus edulis* (Table 2, Fig. 2). Most trees are less than 20 in dbh. *Juniperus* often has more and larger stems than *Pi-*

nus. No clear pattern in regeneration potential is apparent, with some stands lacking seedlings and saplings of one or both trees. The trees and the shrub layer, characterized by 10%–25% cover of *Cercocarpus ledifolius* var. *intricatus*, commonly grow out of cracks and joints in the bedrock. The herb layer consists of about 30 species, which have low constancy and cover (Table 1). Total herb cover rarely exceeds 5%.

It is unlikely that the association receives much use for domestic grazing, which would have little effect in any event because of lack of forage. The exotic *Bromus tectorum* now exists in some stands.

In Colorado the association has been observed in western Moffat County in the study area and in Dinosaur National Monument, as well as in adjoining northwestern Rio Blanco County. It has been reported from Wayne County, Utah, about 250 km southwest of the study area (Dixon 1935) and very likely occurs in other parts of eastern Utah. In the study area the association is limited to the upturned sandstone outcrops east of Limestone Ridge and Irish Canyon.

4. *Cercocarpus ledifolius/Artemisia tridentata* ssp. *wyomingensis-Symphoricarpos oreophilus/Agropyron spicatum*. —This association was found in the study area over a narrow elevational range, above the upper limit of pinyon-juniper woodlands from 2440 to 2560 m. It occurs exclusively on Madison Limestone on steep (25°–35°) slopes on a variety of aspects. Some stands occur as long bands on a slope following a particular layer in the Madison Limestone. Soils are not very different from those of adjoining pinyon-juniper woodlands in terms of average pH (7.36) and electrical conductivity (.43 mmhos/cm) (Table 3).

The association consists of a sparse to moderately dense (185–530 trees/ha) stand of *Cercocarpus ledifolius* (Table 2). Although *Cercocarpus ledifolius* may only reach shrub stature in some areas, it definitely forms woodlands in the study area. Stems as large as 34 in dbh have been observed. *Juniperus scopulorum* and *Pinus edulis* are often present as seedlings or saplings and occasionally as trees. There are generally numerous *Cercocarpus* seedlings and saplings (Table 2). The shrub layer has 10%–25% total cover, with *Artemisia* and *Symphoricarpos* co-dominant. *Agropyron spicatum* dominates the herb layer with 5%–15% cover (Table 3).

Domestic livestock grazing may reduce the amount of *Agropyron spicatum*, resulting in increases in the amount of *Artemisia tridentata* and herbs.

The association is currently not known outside the study area, where it has been located

Table 3. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association number corresponds to that in the text. 4 = *Cercocarpus ledifolius/Artemisia tridentata* ssp. *wyomingensis–Symphoricarpos oreophilus/Agropyron spicatum*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover left of the slash, and percent constancy right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	10 N	10 N	10 N	
Range	101W	101W	101W	
Section	S9	S16	S16	
Elevation (meters)	2470	2460	2560	
Aspect	NE	E	SW	
Soil pH	7.30	7.15	7.65	Avg=7.36
Soil EC (mmhos/cm)	.37	.45	.48	Avg= .43
Plant association number			4	
Plot number	1	2	3	Cov/Con
Shrubs				
Artemisia tridentata ssp. *wyomingensis*	6	15	15	12.0/99
Symphoricarpos oreophilus	4	5	7	5.3/99
Artemisia nova	tr			tr/33
Cercocarpus montanus	1		tr	tr/67
Ribes cereum	1	tr	2	1.2/99
Amelanchier utahensis		tr		tr/33
Fendlerella utahensis		tr		tr/33

Table 3 continued.

Township	10 N	10 N	10 N	
Range	101W	101W	101W	
Section	S9	S16	S16	
Elevation (meters)	2470	2460	2560	
Aspect	NE	E	SW	Avg=7.36
Soil pH	7.30	7.15	7.65	Avg= .43
Soil EC (mmhos/cm)	.37	.45	.48	
Plant association number	4			
Plot number	1	2	3	Cov/Con
Chrysothamnus viscidiflorus			2	.7/33
Pediocactus simpsonii		tr		tr/33
GRAMINOIDS				8.7/99
Agropyron spicatum	6	10	10	1.7/67
Poa fendleriana	3	2		.8/67
Oryzopsis hymenoides		2	tr	tr/33
Bromus tectorum		tr		tr/33
Poa sandbergii			1	tr/33
Agropyron smithii			tr	tr/33
Sitanion hystrix			tr	tr/33
Carex pityophila		tr		
FORBS	5			1.8/67
Claytonia lanceolata				2.3/99
Balsamorhiza hookeri		2	2	2.7/99
var. *hispidula*	3	2	2	2.3/99
Mertensia oblongifolia	4	2	1	tr/67
Senecio integerrimus	4	tr		2.1/99
Petradoria pumila	1	3	tr	tr/33
Collinsia parviflora	3			tr/67
Erigeron eatonii	tr		tr	tr/67
Heuchera parvifolia	tr			tr/67
Lithofragma glabrum	1	tr		tr/67
Lomatium triternatum	1	tr		tr/33
Androstephium breviflorum	tr			tr/67
Antennaria dimorpha	tr			tr/67
Sedum stenopetalum	tr	tr		tr/33
Erysimum asperum	tr	tr		tr/99
Linum lewisii	tr		tr	tr/99
Eriogonum sp.	tr	tr	tr	tr/33
Eriogonum umbellatum	tr			.7/99
Penstemon humilus	tr	tr	1	tr/33
Agoseris glauca	tr			tr/33
Lomatium orientale	tr			tr/33
Selaginella densa	tr			tr/33
Phlox hoodii	tr			tr/33
Castilleja chromosa	tr			tr/67
Petrophytum caespitosum	tr	tr		1.3/33
Arabis sp.		4		tr/33
Haplopappus armerioides		tr		tr/33
Lithospermum ruderale		tr		tr/33
Schoenocrambe linifolia		tr		tr/33
Zigadenus paniculatus		tr		tr/33
Delphinium nuttallianum		tr		tr/33
Erigeron nematophyllus		1		tr/33
Comandra umbellata			tr	.7/33
Descurainia richardsonii			2	tr/33
Cryptantha flavoculata			tr	tr/33
Arabis lignifera			tr	tr/33
Hymenopappus filifolius			tr	tr/33
Stellaria jamesiana			tr	
Penstemon moffattii				

only on the upper slopes of Limestone Ridge. *Cercocarpus ledifolius* stands occur across the northern Great Basin to southeastern Oregon. Many of these have been classified as belonging to a *Cercocarpus ledifolius/Agropyron spicatum* association.

Cercocarpus ledifolius was observed to occur mixed with *Pinus ponderosa* in the Douglas Mountain area, south of the study area. A single stand was located (T11N R101W S19 NE4) that has an overstory of *Cercocarpus ledifolius* with an understory of *Cercocarpus montanus*. Scattered individuals of *Cercocarpus ledifolius* var. *intricatus* also occur in the stand. Because this was the only stand of this sort observed, and no reference to similar vegetation could be found in the literature, it was not described as a separate association.

5. *Artemisia nova/Agropyron spicatum*. — This association occurs exclusively on relatively calcareous parent materials (Browns Park Fm., Madison Limestone). It occupies a wide elevational range from 1700 to 625 m, occurring primarily on northerly facing slopes that are often steep (up to 35°). It occurs at lower elevations on mesa sides and the sides of draws, and at higher elevations it may occur in a broad band above the pinyon-juniper zone. Soils, in spite of developing on a calcareous parent material, have an average pH (7.94) and electrical conductivity (.38 mmhos/cm) not much different from those in pinyon-juniper woodlands on noncalcareous substrata (Table 4).

The association consists of a low shrub layer of sparse (8%–20% cover) *Artemisia nova* (Table 4). At lower elevations (below about 1900 m) *Atriplex confertifolia* may commonly occur and occasionally be abundant. The herb layer, with 15%–30% cover of *Agropyron spicatum*, often overtops the *Artemisia nova*, giving the association a grassland appearance (Fig. 2).

In many stands with abundant domestic livestock grazing signs *Koeleria cristata*, or occasionally *Poa sandbergii*, is much more

Table 4. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 5 = *Artemisia nova/Agropyron spicatum*, 6 = *Artemisia nova/Stipa comata*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy on the left of the slash and percent constancy to the right of the slash. 100 is abbreviated to 99. Soil EC is soil electrical conductivity; its measurement is discussed in the text.

Township	9 N	10 N	9 N	10 N		10 N	9 N	11 N	9 N	
Range	102W	101W	101W	101W		101W	101W	101W	101W	
Section	S12	S14	S5	S9		S34	S2	S28	S3	
Elevation (meters)	1730	2070	1860	2340		1915	1900	2100	1910	
Aspect	N	NE	N	NE		S	S	—	S	
Slope (degrees)	35	5	30	10		2	3	0	2	
Soil pH	8.10	7.85	8.05	7.75	Avg=7.94	8.00	7.90	7.75	7.75	Avg=7.85
Soil EC (mmhos/cm)	.38	.39	.34	.42	Avg= .38	.42	.37	.73	.36	Avg= .47
Plant association number	5					6				
Plot number	1	2	3	4	Cov/Con	1	2	3	4	Cov/Con
Shrubs										
Artemisia nova	8	17	17	20	15.5/99	12	10	8	10	10.0/99
Atriplex confertifolia	1		tr		tr/50					
Ceratoides lanata	tr		tr	tr	tr/75	tr			1	tr/50
Gutierrezia sarothrae		tr			tr/25					
Pediocactus simpsonii	tr	tr		tr	tr/75			tr		tr/25
Artemisia tridentata ssp. *wyomingensis*						tr	tr	tr		tr/75
Tetradymia spinosa							tr			tr/25
Opuntia polyacantha								tr	tr	tr/50
Chrysothamnus viscidiflorus								tr	tr	tr/50
Graminoids										
Agropyron spicatum	25	20	18	20	20.8/99					
Poa sandbergii	5	3	3	2	3.3/99		tr	2	3	1.4/75
Vulpia octoflora	tr				tr/25					
Oryzopsis hymenoides	tr		tr	tr	tr/75	tr	tr	1	tr	.6/99
Koeleria cristata		3	1	4	2.0/75					
Agropyron smithii				tr	tr/25			tr	1	tr/50

Table 4 Continued.

Township	9 N	10 N	9 N	10 N		10 N	9 N	11 N	9 N	
Range	102W	101W	101W	101W		101W	101W	101W	101W	
Section	S12	S14	S5	S9		S34	S2	S28	S3	
Elevation (meters)	1730	2070	1860	2340		1915	1900	2100	1910	
Aspect	N	NE	N	NE		S	S	—	S	
Slope (degrees)	35	5	30	10		2	3	0	2	
Soil pH	8.10	7.85	8.05	7.75	Avg=7.94	8.00	7.90	7.75	7.75	Avg=7.85
Soil EC (mmhos/cm)	.38	.39	.34	.42	Avg= .38	.42	.37	.73	.36	Avg= .47
Plant association number	5					6				
Plot number	1	2	3	4	Cov/Con	1	2	3	4	Cov/Con
Stipa comata						30	25	20	25	25.0/99
Bromus tectorum						1	tr	tr	tr	.6/99
Sitanion hystrix						tr		tr	1	tr/75
FORBS										
Phlox hoodii	4	tr	2	3	2.4/99	tr	tr	2	2	1.3/99
Arenaria hookeri	1				tr/25			tr		tr/25
Astragalus spatulatus	tr				tr/25					
Arenaria fendleri	tr				tr/25					
Erigeron pumilus	tr	tr	tr	tr	tr/99					
Allium textile	tr				tr/25					
Haplopappus acaulis	tr		1	1	.6/75					
Townsendia incana	tr				tr/25			tr		tr/25
Cymopterus fendleri	tr				tr/25					
Zigadenus paniculatus	tr		tr		tr/50					
Crepis occidentalis	tr				tr/25					
Arabis pulchra	tr				tr/25					
Castilleja chromosa	tr			1	tr/50					
Eriogonum tumulosum	tr				tr/25					
Astragalus missouriensis	tr				tr/25					
Erysimum asperum	tr		tr		tr/50		1			tr/25
Physaria acutifolia	tr	tr	tr		tr/75					
Penstemon yampaensis		1			tr/25		tr	1	tr	tr/75
Astragalus chamaeleuce		tr	tr		tr/50		tr			tr/25
Cryptantha flava				tr	tr/25					
Hymenoxys acaulis		tr			tr/25					
Linum lewisii		tr		tr	tr/50					
Penstemon osterhoutii		tr	tr		tr/50					
Caulanthus crassicaulis		tr			tr/25		tr			tr/25
Agoseris heterophylla			tr		tr/25					
Antennaria dimorpha			tr		tr/25					
Lesquerella alpina			tr	1	tr/50					
Schoenocrambe linifolia			tr		tr/25			tr		tr/25
Crepis modocensis			tr		tr/25					
Sedum stenopetalum				tr	tr/25					
Arabis demissa				tr	tr/25					
Eriogonum sp.				tr	tr/25			tr		tr/25
Townsendia incana				tr	tr/25					
Petradoria pumila				tr	tr/25					
Androstephium breviflorum				tr	tr/25					
Descurainia richardsonii						1	2	tr	tr	1.0/99
Lappula redowskii						tr	tr	tr	tr	tr/99
Sphaeralcea coccinea						1	1	1	tr	.9/99
Allium textile						tr	tr	tr		tr/75
Gilia sinuata						tr				tr/25
Delphinium nuttallianum						tr	tr			tr/50
Ipomopsis pumila						tr				tr/25
Eriogonum ovalifolium								1		tr/25
Penstemon fremontii								tr	tr	tr/50
Lesquerella ludoviciana								tr		tr/25
Orobanche fasciculata								tr	tr	tr/50
Cymopterus purpureus									tr	tr/25

abundant than *Agropyron spicatum*. Other species that tend to increase under livestock grazing include *Vulpia octoflora*, *Haplopappus acaulis*, and many other herbs. Moderately grazed sites with lower grass cover tend to have more herbs.

In Colorado the association has been observed only in western Moffat County (the study area), where it occurs from Browns Park north to near the Wyoming border. The association occurs across the northern Great Basin from Wyoming (Thatcher 1959, Tweit and Houston 1980) to northern Nevada (Zamora and Tueller 1973), southern Idaho (Hironaka 1978, Johnson and Pfister 1982, Passey et al. 1982, Sharp and Sanders 1978), and California (Barbour and Major 1977).

6. *Artemisia nova/Stipa comata*. —This association occurs from 1890 to 2165 m in elevation on nearly flat surfaces primarily on the Browns Park Fm. It may also occur on other parent materials on benches, mesa tops, and flat plains. Soils are similar to those of the *Artemisia nova/Agropyron spicatum* association in terms of average pH (7.85) and electrical conductivity (.47 mmhos/cm) (Table 4).

The association consists of a sparse stand of *Artemisia nova* (Table 4) scattered through a dense grass matrix of *Stipa comata* (Fig. 2).

Domestic livestock grazing decreases *Stipa comata* and results in increases in *Poa sandbergii*, *Bromus tectorum*, and forbs. Most stands now have *Poa sandbergii* dominant. though others have dense *Artemisia nova* with very little grass present, or no grass at all.

The association has been observed in Colorado only in western Moffat County, where it has been located only in the vicinity of Limestone Ridge, and in North Park in Jackson County some 200 km east of the study area. It is known to occur across the northern Great Basin to Nevada (Blackburn et al. 1969 a,b,c, Zamora and Tueller 1973) and California (Barbour and Major 1977).

7. *Artemisia tridentata* ssp. *tridentata/Elymus cinereus*.—This association occurs only on relatively flat stream floodplains with or without permanent surface water. Elevations range from about 1980 to 2200 m, though the association has been observed at lower elevations outside the study area. The substrate is Quaternary alluvium. Soils are clayey, with an average pH of 7.75 and electrical conductivity of .44 mmhos/cm (Table 5).

The association (Fig. 3, Table 5) consists of a tall stand of *Artemisia tridentata* ssp. *tridentata*, with 15%–25% cover. *Elymus cinereus*, with 20%–40% cover, dominates the herb layer. *Agropyron smithii*, with 2%–5% cover, is usually present.

The association is prone to invasion by exotic species. Those commonly present now include *Poa pratensis*, *Bromus tectorum*, *Thlaspi arvense*, *Malcomia africana*, and *Melilotus officinalis*. Domestic livestock grazing decreases *Elymus cinereus* and results in increases in the density of *Artemisia tridentata* and these exotic herbs. The environment occupied by the association may be modified from a relatively wide and shallow floodplain to a deep, steep-sided gully if land uses in the stream catchment area result in changes in the timing and intensity of runoff.

The association occurs in scattered locations throughout the study area. It is known to occur in scattered locations throughout Moffat and Rio Blanco counties (Baker 1982b) in Colorado and occurs across the northern Great Basin in Utah (Pammel 1903), northern Nevada (Blackburn et al. 1971, Young et al. 1975), southern Idaho (Hironaka 1978, Johnson and Pfister 1982), to California (Barbour and Major 1977), Oregon, and Washington (Hironaka 1978).

8. *Artemisia tridentata* ssp. *vaseyana/Agropyron spicatum*. —This association occurs only above about 2125 m in elevation in the study area, where it occupies upper slopes and ridge tops, occurring on the Laney Member of the Green River Fm. on flat to moderately steep slopes.

Though many stands of this association were observed in the study area, only one stand was located that was sufficiently free of grazing effects to be usable for sampling. For this reason, this description must be considered preliminary, but because the association is well known and well described in the literature from other parts of its range, it was felt that inclusion of even minimal data from the study area would be beneficial. The association (Table 5, Fig. 3) consists of about 15% cover of *Artemisia tridentata* ssp. *vaseyana*, with minor amounts of *Ceratoides lanata* and *Opuntia polyacantha* present. *Agropyron*

TABLE 5. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 7 = *Artemisia tridentata* ssp. *tridentata/Elymus cinereus*, 8 = *Artemisia tridentata* ssp. *vaseyana/Agropyron spicatum*, 9 = *Artemisia tridentata* ssp. *wyomingensis/Agropyron smithii*, 10 = *Artemisia tridentata* ssp. *wyomingensis/Agropyron spicatum*, 11 = *Artemisia tridentata* ssp. *wyomingensis–Atriplex confertifolia–Grayia spinosa*/Stipa comata*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover for all the plots in the association on the left of the slash and percent constancy to the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	12 N	11 N		10 N	10 N	10 N		10 N	10 N	10 N		9 N	9 N	9 N	
Range	98W	97W		97W	101W	101W		99W	100W	100W		101W	101W	101W	
Section	S34	S3		S3	S12	S2		S9	S27	S35		S12	S18	S17	
Elevation (meters)	2100	2030		2220	1885	2060		2165	2130	2100		1750	1790	1790	
Aspect	NE	N		N	NE	W		NE	SE	SE		NE	SW	SW	
Slope (degrees)	2	1		15	3	4		5	5	2		3	2	3	
Soil pH	7.70	7.80	Avg = 7.75	7.95	8.05	7.85	Avg = 7.95	7.80	7.80	7.65	Avg = 7.75	8.15	8.20	7.70	Avg = 8.02
Soil EC (mmhos/cm)	.45	.42	Avg = .44	.43	.19	.17	Avg = .18	40	.31	.30	Avg = .34	.33	.37	.40	Avg = .37
Plant association number	7			8	9			10				11			
Plot number	1	2	Cov/Con	1	1	2	Cov/Con	1	2	3	Cov/Con	1	2	3	Cov/Con
SHRUBS															
Artemisia tridentata ssp. *tridentata*	15	25	20.0/99												
Chrysothamnus nauseosus	5	1	3.0/99									tr			tr/33
Sarcobatus vermiculatus	tr		tr/50												
Chrysothamnus viscidiflorus	4	tr	2.3/99		tr		tr/50								
Opuntia polyacantha		tr	tr/50	tr					tr	1	tr/67	tr	tr		tr/67
Artemisia tridentata ssp. *vaseyana*				15											
Ceratoides lanata				tr	tr	1	.8/99						tr		tr/33
Artemisia tridentata ssp. *wyomingensis*					8	14	11.0/99	10	17	20	15.7/99	20	10	14	14.7/99
Tetradymia spinosa					2	tr	1.3/99								
Atriplex confertifolia					2	tr	1.3/99	2			.7/99	4	4	3	3.7/99
Artemisia spinescens					tr		tr/50								
Atriplex gardneri					tr		tr/50								
Grayia spinosa												3	tr	3	2.3/99
GRAMINOIDS															
Elymus cinereus	40	20	30.0/99												
Poa pratensis	tr	1	.8/99												
Agropyron smithii	2	5	3.5/99	tr	20	15	17.5/99	3		tr	1.2/67				
Bromus tectorum		tr	tr/50									6	tr	1	2.5/99
Sitanion hystrix		tr	tr/50		tr		tr/50		tr		tr/33	1	tr	tr	.7/99
Oryzopsis hymenoides		tr	tr/50	tr		tr	tr/50		1	tr	tr/67	tr		tr	tr/67
Agropyron spicatum				20				15	20	25	20.0/99				
Poa sandbergii				3	1	2	1.5/99	3	4	4	3.7/99	2	tr	1	1.2/99
Koeleria cristata				tr				2			.7/33				
Stipa comata						tr	tr/50					12	25	25	20.7/99
Poa fendleriana										tr	tr/33	tr			tr/33
Vulpia octoflora												4	tr	5	3.2/99
FORBS															
Thlaspi arvense	3	tr	1.8/99												
Cirsium vulgare	tr		tr/50												
Cryptantha flavoculata	tr		tr/50					tr	tr		tr/67				
Mertensia oblongifolia	3	tr	1.8/99												
Schoenocrambe linifolia	1		tr/50						tr		tr/33				
Descurainia sophia	tr	1	.8/99												
Taraxacum officinale	tr		tr/50												
Atriplex sp.	tr	tr	tr/99												
Malcomia africana	tr	tr	tr/99												
Melilotus officinalis	tr		tr/50												
Grindelia sp.	3		1.5/50												
Penstemon fremontii	tr		tr/50	tr		tr	tr/50								
Ipomopsis congesta	tr		tr/50										tr		tr/33
Vicia americana		tr	tr/50												
Stanleya pinnata		tr	tr/50												
Thelypodiopsis elegans		tr	tr/50												
Allium textile				tr	tr	tr	tr/99	tr			tr/33	tr			tr/33
Eriogonum ovalifolium				1					tr		tr/33				
Arenaria fendleri				tr											
Linum lewisii				tr											
Commandra umbellata				tr											
Haplopappus acaulis				1				3	tr		1.2/67				
Phlox hoodii				2	tr	1	.8/99	tr	tr	2	1.0/99			tr	tr/33
Draba oligosperma				tr											
Astragalus spatulatus				tr											
Eriogonum sp.				tr	tr		tr/50								
Astragalus purshii				tr				tr	tr	tr	tr/99				
Townsendia incana				tr	tr	tr	tr/99								

Table 5 continued.

Township	12 N	11 N			10 N	10 N	10 N			10 N	10 N	10 N			9 N	9 N	9 N		
Range	98W	97W			97W	101W	101W			99W	100W	100W			101W	101W	101W		
Section	S34	S3			S3	S12	S2			S9	S27	S35			S12	S18	S17		
Elevation (meters)	2100	2030			2220	1885	2060			2165	2130	2100			1750	1790	1790		
Aspect	NE	N			N	NE	W			NE	SE	SE			NE	SW	SW		
Slope (degrees)	2	1			15	3	4			5	5	2			3	2	3		
Soil pH	7.70	7.80	Avg	7.75	7.95	8.05	7.85	Avg	7.95	7.80	7.80	7.65	Avg	7.75	8.15	8.20	7.70	Avg	8.02
Soil EC (mmhos/cm)	.45	.42	Avg	.44	.43	.19	.17	Avg	.18	.40	.31	.30	Avg	.34	.33	.37	.40	Avg	.37
Plant association number	7				8	9				10					11				
Plot number	1	2	Cov/Con		1	1	2	Cov/Con		1	2	3	Cov/Con		1	2	3	Cov/Con	
Phlox longifolia					tr					tr		tr	tr/67						
Arabis demissa					tr														
Erysimum asperum					tr														
Sphaeralcea coccinea					tr	tr		tr/50								tr		tr/33	
Castilleja chromosa					tr	tr		tr/50		1			tr/33						
Descurainia richardsonii						tr	tr	tr/99			tr	tr	tr/67			tr	1	tr/67	
Cymopterus bulbosus						tr	tr	tr/99											
Zigadenus paniculatus						tr		tr/50											
Astragalus chamaeleuce						tr	tr	tr/99											
Lappula redowskii						tr		tr/50							tr		tr	tr/67	
Physaria acutifolia							tr	tr/50											
Cryptantha sp.							tr	tr/50											
Chaenactis douglasii							tr	tr/50											
Arabis pulchra							tr	tr/50											
Crepis modocensis							tr	tr/50											
Xylorhiza venusta							tr	tr/50											
Machaeranthera grindelioides							tr	tr/50											
Astragalus detritalis										2			.7/33						
Trifolium gymnocarpon										1	tr	tr	.7/99						
Lomatium sp.										tr			tr/33						
Crepis occidentalis										tr	tr	tr	tr/99						
Balsamorhiza hookeri var. *hispidula*											4		1.3/33						
Erigeron divergens											tr	tr	tr/67						
Astragalus megacarpus											tr		tr/33						
Cordylanthus ramosus												tr	tr/33						
Delphinium nuttallianum															tr			tr/33	
Ipomopsis pumila															tr	tr	tr	tr/99	
Agoseris heterophylla															tr		tr	tr/67	
Erigeron pumilus															tr			tr/33	
Lepidium densiflorum																tr	1	tr/67	
Camissonia contorta																	tr	tr/33	
Mentzelia albicaulis																	tr	tr/33	

spicatum, with about 20% cover, dominates the understory. *Poa sandbergii* commonly has 2%–3% cover.

Domestic livestock grazing has altered the composition of nearly all stands in the study area, resulting in the decline or loss of *Agropyron spicatum* and widespread replacement by *Poa sandbergii*, accompanied by increased density of *Artemisia tridentata* ssp. *vaseyana*. Herb density may also be very high.

The association has been located in Colorado only in the study area and in Middle Park, Grand County (Terwilliger and Tiedeman 1978). It is known to occur from western Wyoming (Beetle 1961) to Idaho (Hironaka 1978, Johnson and Pfister 1982) and Oregon (Hironaka 1978). In the study area it has been observed primarily in the Vermillion Bluffs and Sevenmile Ridge area.

9. *Artemisia tridentata* ssp. *wyomingensis*/*Agropyron smithii*.—This association occurs on slight convexities on flat to gently rolling plains formed in shales of the Mancos Fm., Green River Fm., or Wasatch Fm. It occurs in the study area from 1830 to 2130 m in elevation. Soils have an average pH of 7.95 and electrical conductivity of .19 mmhos/cm (Table 5). Over a broad area the association occurs in an alternating mosaic with the *Atriplex gardneri*/*Oryzopsis hymenoides* association, which occurs on more saline, more clayey soils, often in gentle concavities, on the rolling plains. Boundaries between these two associations may be very abrupt, apparently reflecting abrupt changes in soil properties.

The association consists of a sparse stand of *Artemisia tridentata* ssp. *wyomingensis* (Table 5, Fig. 3) scattered through a grass matrix. *Agropyron smithii* has 15%–20% cover. *Poa sandbergii* commonly has 1%–2% cover.

Domestic livestock grazing may decrease *Agropyron* and result in increases in

Fig. 3. (a) *Artemisia tridentata* ssp. *tridentata/Elymus cinereus*, (b) *Artemisia tridentata* ssp. *vaseyana/Agropyron spicatum*, (c) *Artemisia tridentata* ssp. *wyomingensis/Agropyron smithii*, (d) *Artemisia tridentata* ssp. *wyomingensis/Agropyron spicatum*, (e) *Artemisia tridentata* ssp. *wyomingensis–Atriplex confertifolia–Grayia spinosa*/Stipa comata*, (f) *Atriplex confertifolia/Agropyron spicatum*, (g) *Atriplex confertifolia/Elymus salina*, (h) *Atriplex confertifolia/Stipa comata*.

Artemisia density, but, in general, probably due to the rhizomatous growth form of *Agropyron smithii*, the association is moderately resistant to alteration from domestic grazing. Many stands, however, have lost *Agropyron smithii* dominance completely and now have the less palatable grass *Poa sandbergii* as the understory dominant.

This is a very common association within the study area, but it is found only north and east of the Browns Park Formation area that occurs in the vicinity of Limestone Ridge and in Browns Park. It has been located in Colorado in the Piceance Basin in Rio Blanco County (Baker 1982b) and in Middle Park in Grand County (Terwilliger and Tiedeman 1978), and it probably occurs in other areas of northwestern Colorado. It also occurs in western Wyoming (Johnson and Pfister 1982) and in western New Mexico (Donart et al. 1978). It has not been reported from other western states.

10. *Artemisia tridentata* ssp. *wyomingensis/Agropyron spicatum*.—This association may occur in the study area from about 1980 to 2440 m in elevation, on gently rolling slopes and flat benches, on a variety of parent materials including the Laney Member of the Green River Fm. and the Browns Park Fm. Soils have an average pH of 7.75 and an electrical conductivity of .34 mmhos/cm (Table 5).

The association consists of about 10%–20% cover of *Artemisia tridentata* ssp. *wyomingensis* (Table 5, Fig. 3), with an understory of 15%–25% cover of *Agropyron spicatum*. *Poa sandbergii* typically has 3%–5% cover.

Domestic livestock grazing may decrease *Agropyron spicatum* and result in increases in *Poa sandbergii*, *Bromus tectorum*, and *Tetradymia spinosa*. Many stands now have *Poa sandbergii* dominant and appear superficially similar to overgrazed stands of the *Artemisia tridentata* ssp. *wyomingensis/Agropyron smithii* association. Usually it will be possible to find some plants of *Agropyron smithii* or *Agropyron spicatum* in even the most altered stands, allowing identification of the appropriate former association. These observations on the effect of domestic grazing are similar to those reported for the association in other areas (Mueggler and Stewart 1980, Tweit and Houston 1980).

The association is known in Colorado from northern Larimer County (Hess 1981), North Park in Jackson County (Smith 1966), Middle Park in Grand County (Terwilliger and Tiedeman 1978), and the study area in northern Moffat County and has been observed by the senior author in southern Routt County. Within the study area it was observed primarily along Vermillion Bluffs and north toward Powder Wash. The association occurs across the northern Great Basin from western Wyoming (Tweit and Houston 1980) and Montana (Mueggler and Stewart 1980) to Idaho (Hironaka 1978, Johnson and Pfister 1982) and Oregon (Hironaka 1978).

11. *Artemisia tridentata* ssp. *wyomingensis–Atriplex confertifolia–Grayia spinosa*/ *Stipa comata*.—This association is restricted to sandy soils formed in the Browns Park Fm. It occurs on gently rolling hills, flat benches, and plains from 1700 to 1980 m in elevation. It may also occur on sandy hummocks and convexities in an area of finer-textured soils. Soils have an average pH of 8.02 and an electrical conductivity of .37 mmhos/cm (Table 5).

The association consists of a mixed shrub layer (Table 5, Fig. 3), with *Artemisia tridentata* ssp. *wyomingensis* generally most abundant (10%–20% cover) but *Atriplex confertifolia* usually co-dominant. *Grayia spinosa* may be uncommon or very abundant, but it is always present. The herb layer is dominated by *Stipa comata*, with 12%–25% cover.

Domestic livestock grazing decreases *Stipa comata* and results in increases in the exotic grass *Bromus tectorum* and other annual weeds. Most stands in the range of the association now are dominated by *Bromus tectorum*. A soil cryptogam layer, which has about 5% cover on relatively ungrazed sites, is absent on more grazed sites, probably due to trampling.

The association is currently known only from Browns Park in western Moffat County, Colorado. It may extend into Utah in Browns Park. It was, prior to livestock grazing, the predominant vegetation type in Browns Park, occurring over a large area.

12. *Atriplex confertifolia/Agropyron spicatum*.—This association occurs in the study area from about 1950 to 2200 m in elevation, most often on northerly facing slopes, but also on other aspects. Slopes are shallow to moder-

ately steep (up to about 25°). It occurs on side-slopes of draws and on gently sloping benches on two parent materials in the study area: the Cathedral Bluffs Tongue of the Wasatch Fm. and the Laney Member of the Green River Fm. Soils have an average pH of 7.90 and an electrical conductivity of .31 (Table 6).

The association has a sparse shrub layer composed of 4%–8% cover of *Atriplex confertifolia* (Table 6, Fig. 3) and often a small amount of *Ceratoides lanata*. *Agropyron spicatum* dominates the herb layer with 15%–30% cover, giving the association a grassland appearance.

Domestic livestock grazing decreases *Agropyron spicatum*, resulting in increases in *Poa sandbergii* and *Tetradymia spinosa*. Many of the stands of this association have been grazed primarily by sheep. Often, sheep-grazed stands have low forb density and *Atriplex confertifolia* plants have very poor vigor, with part of the crowns dead. *Agropyron spicatum* plants tend to have better vigor and greater cover on most sheep-grazed areas than on cattle-grazed sites.

The association has not been reported to date from outside the study area, where it is found only in the northern part of the area between Vermillion Creek and the Little Snake River. Since the association occurs within a few miles of Wyoming, and similar habitat occurs there, it is likely that it will eventually be found in Sweetwater County.

13. *Atriplex confertifolia/Elymus salina*. —This association occurs from 1950 to 2130 m in elevation in the study area on shallow to steep slopes with a northerly aspect. Parent materials include the Cathedral Bluffs Tongue of the Wasatch Fm. and the Laney Member of the Green River Fm. Soils are the most saline observed in the study area, with an average electrical conductivity of 1.16 mmhos/cm and pH of 7.77 (Table 6). Soils characteristically are shaley, with a surface layer of sandstone fragments. This sandstone surface layer commonly occurs throughout the range of the association.

The association contains a sparse shrub layer dominated by *Atriplex confertifolia* with 5%–10% cover (Table 6). *Sarcobatus vermiculatus*, *Artemisia tridentata* ssp. *wyomingensis*, and *Ceratoides lanata* are often present in small quantities. *Elymus salina* dominates the herb layer with 20%–30% cover. When flowering, this grass may obscure the shrub layer, giving the association a grassland appearance (Fig. 3).

Domestic livestock grazing decreases *Elymus salina* and results in increases in *Atriplex confertifolia* and *Poa sandbergii*.

The association is now known to occur in Colorado in scattered localities from northern Montrose County and Delta and Mesa counties, where it occurs at the boundary between Mancos shale and Mesa Verde Group sandstones (Baker, unpublished data) to the Piceance Basin in Rio Blanco County on Green River Fm. (Baker 1982b) and north to the study area. Within the study area it occurs in the area between Vermillion Creek and the Little Snake River. It has not been reported outside Colorado to date, but it has been observed by the senior author in eastern Grand

TABLE 6. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 12 = *Atriplex confertifolia/Agropyron spicatum*, 13 = *Atriplex confertifolia/Elymus salina*, 14 = *Atriplex confertifolia/Stipa comata*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover for all the plots in the association on the left of the slash and percent constancy to the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	10 N	10 N	10 N	10 N	10 N			10 N	10 N	10 N			12 N	12 N	12 N	12 N		
Range	99W	99W	100W	100W	96W			100W	100W	96W			99W	98W	98W	96W		
Section	S5	S6	S22	S13	S7			S15	S22	S7			S25	S30	S25	S20		
Elevation (meters)	2070	2050	1960	2190	2090			1965	1980	2065			2100	2090	2120	2170		
Aspect	NNE	NW	NE	NW	NE			NE	NW	NE			—	—	NE	N		
Slope (degrees)	5	10	20	20	15			20	25	5			—	—	5	3		
Soil pH	7.95	7.95	7.90	7.80	—	Avg	7.90	7.85	7.75	7.70	Avg	7.77	7.95	8.05	7.85	7.75	Avg	7.90
Soil EC (mmhos/cm)	.25	.28	.38	.34	—	Avg	.31	1.43	.36	1.70	Avg	1.16	.34	.32	46	.03	Avg	.29
Plant association number	12							13					14					
Plot number	1	2	3	4	5	Cov/Con		1	2	3	Cov/Con		1	2	3	4	Cov/Con	
SHRUBS																		
Atriplex confertifolia	5	5	6	6	5	5.4/99		7	8	5	6.7/99		5	4	5	4	4.5/99	
Tetradymia spinosa	tr	1	tr	1		.6/80		tr	tr		tr/67							
Artemisia pedatifida	tr					tr/20									tr		tr/25	
Atriplex gardneri	tr					tr/20			tr	tr	tr/67		tr	tr		tr	tr/75	
Ceratoides lanata		tr	tr		tr	tr/60			tr		tr/33		tr	2	2	tr	1.3/99	

Table 6 continued.

Township	10 N	10 N	10 N	10 N	10 N			10 N	10 N	10 N			12 N	12 N	12 N	12 N		
Range	99W	99W	100W	100W	96W			100W	100W	96W			99W	98W	98W	96W		
Section	S5	S6	S22	S13	S7			S15	S22	S7			S25	S30	S25	S20		
Elevation (meters)	2070	2050	1960	2190	2090			1965	1980	2065			2100	2090	2120	2170		
Aspect	NNE	NW	NE	NW	NE			NE	NW	NE			—	—	NE	N		
Slope (degrees)	5	10	20	20	15			20	25	5			—	—	5	3		
Soil pH	7.95	7.95	7.90	7.80	—	Avg	7.90	7.85	7.75	7.70	Avg	7.77	7.95	8.05	7.85	7.75	Avg	7.90
Soil EC (mmhos/cm)	.25	.28	.38	.34	—	Avg	.31	1.43	.36	1.70	Avg	1.16	.34	.32	.46	03	Avg	.29
Plant association number	12							13					14					
Plot number	1	2	3	4	5	Cov/Con		1	2	3	Cov/Con		1	2	3	4	Cov/Con	
Artemisia frigida					1	tr/20												
Opuntia polyacantha					tr	tr/20				tr	tr/33		tr		tr		tr/50	
Sarcobatus vermiculatus								tr		tr	tr/67							
Artemisia tridentata ssp. *wyomingensis*									tr	tr	tr/67							
Chrysothamnus viscidiflorus										tr	tr/33		tr		1	1	.6/75	
Artemisia spinescens														tr	tr		tr/50	
GRAMINOIDS																		
Agropyron spicatum	28	25	20	27	22	24.4/99												
Hilaria jamesii	3	3				.7/20							1				tr/25	
Poa sandbergii	2	1	1	1	4	1.8/99		2	2	3	2.3/99		4	5	4	1	3.5/99	
Stipa comata	tr					tr/20							20	17	25	17	19.8/99	
Sitanion hystrix		tr			tr	tr/40			tr	tr	tr/67							
Bromus tectorum		tr				tr/20												
Oryzopsis hymenoides		tr	tr	tr		tr/60			tr	tr	tr/67		2	2	3	6	3.3/99	
Elymus salina			8		2	2.0/40		22	28	25	25.0/99							
Agropyron smithii													tr	1	4		1.4/75	
Carex filifolia													tr				tr/25	
FORBS																		
Arenaria fendleri	1	1	tr			tr/60			tr		tr/33							
Crepis occidentalis	1	tr				tr/40												
Phlox hoodii	3	2	1	1	2	1.8/99		2	1	2	1.7/99		2		1	1	1.0/75	
Erigeron compactus var. *consimilis*	1	tr	tr	tr	tr	tr/99		1			tr/33							
Balsamorhiza hookeri var. *hispidula*	1					tr/20												
Machaeranthera grindelioides	tr	tr	1	tr	tr	tr/99												
Physaria acutifolia	tr	tr	tr			tr/60				tr	tr/33							
Haplopappus armerioides	2	1	1			.8/60		tr		tr	tr/67							
Astragalus detritalis	tr					tr/20												
Lygodesmia grandiflora	1	tr				tr/40												
Ipomopsis congesta	tr	1				tr/40										tr	tr/25	
Thelypodiopsis elegans	tr					tr/20				tr	tr/33							
Arenaria hookeri	1		tr	2	3	1.3/80			tr		tr/33					tr	tr/25	
Haplopappus acaulis	tr	tr		tr		tr/60												
Townsendia incana	tr	tr		tr		tr/60								tr	tr		tr/50	
Penstemon fremontii	tr	tr	tr			tr/60			tr		tr/33							
Stanleya pinnata	tr		tr			tr/40		tr	tr		tr/67							
Hymenoxys richardsonii		tr		tr		tr/40												
Descurainia richardsonii		tr				tr/20							2	tr	tr		.8/75	
Lappula redowskii		tr				tr/20				tr	tr/33		tr	tr	tr		tr/75	
Cymopterus acaulis		tr			tr	tr/40												
Astragalus chamaeleuce		tr		tr	tr	tr/60		tr			tr/33		tr			tr	tr/50	
Arabis demissa		tr				tr/20												
Chaenactis douglasii		tr				tr/20												
Castilleja chromosa			tr			tr/20												
Eriogonum umbellatum			tr			tr/20												
Sphaeralcea coccinea				tr		tr/20		tr			tr/33				1		tr/25	
Calochortus nuttallii								tr			tr/33							
Xylorhiza glabriuscula								1			tr/33							
Camissonia scapoidea								tr			tr/33							
Allium textile									tr	tr	tr/67		1		tr	tr	tr/75	
Cryptantha sericea									tr	tr	tr/67							
Schoenocrambe linifolia										tr	tr/33				tr		tr/25	
Descurainia sophia										tr	tr/33							
Cordylanthus ramosus										tr	tr/33							
Phlox longifolia										tr	tr/33							
Lesquerella ludoviciana													tr			1	tr/50	
Gilia leptomeria													tr				tr/25	
Nemophila breviflora													tr				tr/25	
Eriogonum sp.													tr			tr	tr/50	
Arabis pulchra													tr				tr/25	
Oenothera pallida													tr				tr/25	
Ipomopsis pumila													tr				tr/25	
Eriogonum ovalifolium													tr				tr/25	
Cymopterus bulbosus														tr			tr/25	
Erigeron pumilus															tr		tr/25	

County, Utah, in the Grand Valley. The total range of *Elymus salina* and, consequently, the maximum potential range of this association are now known to be essentially the upper Colorado River Basin in eastern Utah, western Colorado, and southwestern Wyoming (Barkworth and Atkins 1984).

14. *Atriplex confertifolia/Stipa comata.* — This association occurs in the study area from 2070 to 2200 m in elevation, where it occupies relatively flat or gently sloping uplands. Parent materials include the Cathedral Bluffs Tongue of the Wasatch Fm. and the Laney Member of the Green River Fm. Soils have a sandier texture than other *Atriplex confertifolia* associations in the study area, but average soil pH (7.90) and average electrical conductivity (.29 mmhos/cm) are not very different (Table 6).

The association has a sparse shrub layer (Table 6, Fig. 3) dominated by *Atriplex confertifolia*, with 4% or 5% cover. *Ceratoides lanata* is often present but may have only trace cover. *Stipa comata* dominates the herb layer, with 15%–30% cover. *Oryzopsis hymenoides* and *Poa sandbergii* are always present, generally with 2%–6% cover each.

Domestic livestock grazing generally decreases *Stipa comata* and results in increases in *Poa sandbergii*. Many stands of this association have been grazed primarily by sheep. In these stands there may be very low forb cover and diversity, and *Atriplex confertifolia* plants may have very low vigor, often with parts of the crown dead. *Stipa comata* often retains better cover and vigor in sheep-grazed than in cattle-grazed stands.

The association has not currently been reported from outside the study area, where it occurs in the area between Vermillion Creek and the Little Snake River. Because it occurs within a few miles of the Wyoming border and similar habitat extends into Wyoming, it may eventually be documented from Sweetwater County.

15. *Atriplex gardneri/Elymus salina.* — The association occurs in the study area from 1890 to 2130 m in elevation on flat to very gently sloping benches, ridges, and saddles. Parent materials include the Bridger Fm. and the Laney Member of the Green River Fm. Soils often are very clayey and have an average pH of 8.01 and electrical conductivity of .35 mmhos/cm (Table 7).

The association (Table 7, Fig. 4) has a sparse and low shrub layer dominated by *Atriplex gardneri*, with 4%–6% cover. *Ceratoides lanata* is always present, but usually has less than 1% cover. The herb layer consists of 20%–30% cover of *Elymus salina*, as well as small amounts of *Poa sandbergii* and *Oryzopsis hymenoides*.

Domestic livestock grazing decreases *Elymus salina* and results in increases in *Poa sandbergii*, *Sitanion hystrix*, and weedy forbs such as *Descurainia* and *Lappula*.

In Colorado the association occurs on north-facing Mancos shale hills in western Mesa County (Baker, unpublished data) and in the study area, where it was located only on the ridges immediately west of the Little Snake River from Highway 318 north to near the Wyoming state line. It has not been reported from Utah or Wyoming to date, though it occurs near both state lines.

16. *Atriplex gardneri/Oryzopsis hymenoides.* —This association occurs in the study area from 1980 to 2200 m in elevation on flat to gently sloping mesa tops, plateaus, rolling plains, and gentle hills. Parent materials are the Luman Tongue of the Green River Fm. and the Niland and Cathedral Bluffs Tongues of the Wasatch Fm. Soils are very clayey, and have an average pH of 8.01 and electrical conductivity of .39 mmhos/cm (Table 7).

The association (Table 7, Fig. 4) consists of a sparse shrub layer dominated by the low-growing shrub *Atriplex gardneri*, with 6%–8% cover, lesser amounts (trace to 2% cover) of *Artemisia spinescens*, and often small amounts of *Ceratoides lanata*. *Oryzopsis hymenoides* dominates the herb layer, with 10%–25% cover. *Sitanion hystrix*, with trace%–4% cover, and *Poa sandbergii*, with trace%–4% cover, are regular components of the association. The forb component is very sparse and variable. But, because none of the sampled stands were entirely free of some signs of grazing, the variability of the forb component may be a reflection of past grazing history more than presettlement conditions.

Grazing by domestic livestock tends to result in the loss of *Oryzopsis hymenoides*. Either *Sitanion hystrix* or *Poa sandbergii* or

TABLE 7. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 15 = *Atriplex gardneri/Elymus salina*, 16 = *Atriplex gardneri/Oryzopsis hymenoides*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover on the left of the slash and percent constancy on the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	9 N	9 N	8 N	10 N	11 N		12 N	12 N	11 N	11 N	11 N	11 N	
Range	97W	97W	97W	96W	96W		101W	101W	101W	100W	99W	97W	
Section	S25	S35	S3	S8	S17		S24	S20	S9	S21	S1	S3	
Elevation (meters)	2010	1980	1915	2050	2110		2125	2135	2090	2050	2085	2025	
Aspect	S	SSW	WNW	S	N		—	—	SW	S	SE	W	
Slope (degrees)	3	2	3	4	1		1	0	4	4	3	2	
Soil pH	8.30	7.90	7.85	8.15	7.85	Avg 8.01	7.65	8.00	8.00	8.15	8.05	8.20	Avg 8.01
Soil EC (mmhos/cm)	.38	.36	.28	.39	.34	Avg .35	.36	.34	.45	.39	.44	.37	Avg .39
Plant association number	15						16						
Plot number	1	2	3	4	5	Cov/Con	1	2	3	4	5	6	Cov/Con
SHRUBS													
Atriplex gardneri	6	5	5	6	5	5.4/99	8	7	8	7	6	6	7.0/99
Ceratoides lanata	tr	1	tr	tr	tr	.6/99	tr	2	5			1	1.4/67
Artemisia spinescens			tr			tr/20	tr	3	1	1		2	1.3/83
Atriplex confertifolia			tr		tr	tr/40	tr						tr/17
Opuntia polyacantha	tr		1		tr	tr/60				tr			tr/17
Artemisia pedatifida								tr					tr/17
Chrysothamnus sp.											1		tr/17
GRAMINOIDS													
Elymus salina	27	30	22	25	25	25.8/99							
Poa sandbergii	2	2	2	4	5	3.0/99	1	4		2	tr	4	1.9/83
Oryzopsis hymenoides	tr	2	3	1	tr	1.4/99	10	10	20	15	12	25	15.3/99
Sitanion hystrix	tr	1	1	2		.9/80	4	3	tr	3	3	3	2.8/99
Bromus tectorum	tr					tr/20				1			tr/17
Agropyron smithii											tr	tr	tr/33
X *Stiporyzopsis* X *bloomeri*												tr	tr/17
FORBS													
Phlox hoodii	2	tr	3	1	2	1.7/99	tr	1		tr		tr	tr/67
Descurainia sophia	1	1	1	tr		.7/80							
Lappula redowskii	tr	1	tr	1	tr	.7/99	tr		tr	6	tr	2	1.6/83
Phlox longifolia	tr		tr	tr		tr/60							
Calochortus nuttallii	tr					tr/20							
Cymopterus acaulis	tr					tr/20							
Allysum desertorum	tr					tr/20							
Allium textile	tr		tr	tr	tr	tr/80	tr	tr				tr	tr/50
Camelina microcarpa		1	tr			tr/40							
Lepidium perfoliatum		tr				tr/20							
Trifolium gymnocarpon			tr			tr/20							
Camissonia scapoidea				1		tr/20				tr	tr		tr/33
Nemophila breviflora				tr		tr/20							
Cymopterus bulbosus				tr		tr/20	tr				tr		tr/33
Monolepis nuttalliana				tr		tr/20						1	tr/17
Thelypodiopsis elegans				tr		tr/20					tr		tr/17
Ipomopsis congesta					tr	tr/20							
Arabis lignifera					tr	tr/20							
Astragalus chamaeleuce					tr	tr/20							
Erigeron compactus var. *consimilis*					tr	tr/20							
Townsendia incana					tr	tr/20	tr	tr					tr/33
Haplopappus acaulis					tr	tr/20							
Lesquerella ludoviciana					tr	tr/20							
Descurainia richardsonii							1	tr	tr				tr/50
Sphaeralcea coccinea							tr	tr		tr			tr/50
Halogeton glomeratus							tr			tr		tr	tr/50
Eriogonum ovalifolium								tr					tr/17
Ipomopsis pumila										tr			tr/17
Xylorhiza venusta										tr			tr/17
Vicia americana											1		tr/17
Stanleya pinnata											tr		tr/17
Rumex sp.											tr		tr/17

both will tend to replace *Oryzopsis*. All but a very small percentage of the range of this association now is dominated by one or both of these grasses. In many of these stands *Oryzopsis* can still be found in very small quantities. These surviving *Oryzopsis* plants are nearly always of very poor vigor, with dead centers, no litter, no flower stalks, and short and sparse foliage. Two other grazing-induced forms of this association occur. In one, the exotic *Halogeton glomeratus* dominates in the absence, or near absence, of perennial grass.

Fig. 4. (a) *Atriplex gardneri/Elymus salina*, (b) *Atriplex gardneri/Oryzopsis hymenoides*, (c) *Cercocarpus ledifolius* var. *intricatus/Agropyron spicatum*, (d) *Cercocarpus montanus/Agropyron spicatum*, (e) *Agropyron smithii* Great Basin Grassland, (f) *Agropyron spicatum–Arenaria hookeri**, (g) *Carex aquatilis* Wetland, (h) *Eleocharis palustris* Wetland.

In the other, a nearly pure stand of *Atriplex gardneri* occurs, with only a few annual weeds present.

The association has currently been described only from the study area, where it formerly covered a wide area primarily on the plateaus and benches adjoining Vermillion Creek and Dry Creek. The degraded forms of the association, with either *Sitanion hystrix* or *Poa sandbergii* dominant, have been observed by the senior author in southern Sweetwater County, Wyoming, but it is not known whether good condition stands are still extant in Wyoming, or how far north the association formerly occurred.

17. *Cercocarpus ledifolius* var. *intricatus*/*Agropyron spicatum*.—This association occurs above the pinyon-juniper zone, from about 2375 to 2550 m in elevation. It occupies very rocky ridge tops and upper slopes (Fig. 4) on exposures of Madison Limestone and Morgan Fm. Slopes range from 0° to 15°. Aspects are often northerly. Soils are very rocky and have an average pH of 7.80 with an electrical conductivity of .41 (Table 8).

The association has a dense shrub layer, with 35%–40% cover of *Cercocarpus ledifolius* var. *intricatus* and a small amount (less than 2% cover) of *Cercocarpus montanus*. The herb layer is dominated by *Agropyron spicatum*, with 5%–10% cover. *Carex pityophila*, with 5%–10% cover, and *Koeleria cristata*, with trace %–3% cover, are generally present.

Domestic livestock grazing may decrease *Agropyron spicatum* and result in increases in forbs and in *Cercocarpus* density. Most known sites are, however, far from water and generally poor in forage, so that heavy grazing is unlikely.

The association has not been described from outside the study area. It occurs within the study area only on Limestone Ridge, where it covers considerable area.

18. *Cercocarpus montanus*/*Agropyron spicatum*.—This association commonly occurs on steep northerly facing slopes between 1830 and 2130 m elevation in the study area. It occurs on Browns Park Fm. as well as several other parent materials.

Though many stands of the association were observed in the study area, only one stand could be located that was sufficiently undisturbed to be usable for sampling. The description and data are thus tentative, though the association is well known to the north in Wyoming. The association (Table 8, Fig. 4) in the study area contains a moderately dense shrub layer dominated by *Cercocarpus montanus*, with about 20% cover. *Agropyron spicatum* dominates the herb layer, with about 15% cover. Other commonly associated grasses include *Poa fendleriana* and *Poa sandbergii*.

The association occurs in scattered locations in western Wyoming. It is probably at or near its southern range limit in Moffat County, where it was located primarily in the area north of Limestone Ridge and west of Vermillion Creek, extending north to the Wyoming border.

19. *Agropyron smithii* Great Basin Grassland.—This association occurs in flat to gently sloping basins and along ephemeral creeks, between 1980 and 2130 m in elevation in the study area. Soils are very clayey and have an average pH of 7.78 and electrical conductivity of .32 mmhos/cm (Table 9). The parent material is Quaternary alluvium.

The association consists primarily of a dense stand of *Agropyron smithii*, with about 50% cover. Associated forbs and grasses are very variable.

Domestic livestock grazing has been reported (Christensen and Welsh 1963) to be capable of converting this association to solid sagebrush in as little as seven years of grazing. Livestock grazing may also enable the establishment of annual exotic weeds, such as *Conringia orientalis*, *Polygonum aviculare*, and *Lappula redowskii*.

The association has been observed in Colorado by the senior author in eastern Moffat County along Fortification Creek north of Craig. It also occurs in central Utah (Christensen and Welsh 1963, Christensen and Johnson 1964); in northeastern Nevada (Miller et al. 1982), where it occurs in a similar topographic position on saline soils; and in northeastern Arizona (Nichol 1937), where it occurs on "heavy gumbo soils."

20. *Agropyron spicatum*–*Arenaria hookeri**.—This association occurs exclusively on rocky exposures of Madison Limestone on open, wind-exposed summits that are alpine-like (Fig. 4) in that they are above the upper pinyon-juniper treeline and are on windy

TABLE 8. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 17 = *Cercocarpus ledifolius* var. *intricatus*/*Agropyron spicatum*, 18 = *Cercocarpus montanus*/*Agropyron spicatum*. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover on the left of the slash and percent constancy on the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	11 N	11 N	11 N		11 N
Range	101W	101W	101W		101W
Section	S19	S29	S19		S35
Elevation (meters)	2375	2530	2550		1995
Aspect	N	N	S		NNE
Slope (degrees)	10	2	4		30
Soil pH	7.95	7.85	7.60	Avg=7.80	7.95
Soil EC (mmhos/cm)	.40	.38	.44	Avg= .41	.35
Plant association number			17		18
Plot number	1	2	3	Cov/Con	1
SHRUBS					
Cercocarpus ledifolius var. *intricatus*	40	35	35	36.7/99	
Cercocarpus montanus	2	tr	tr	1.0/99	20
Artemisia nova	1			tr/33	
Artemisia frigida	tr			tr/33	
Symphoricarpos oreophilus	tr			tr/33	
Chrysothamnus viscidiflorus			tr	tr/33	
Artemisia tridentata ssp. *wyomingensis*					tr
GRAMINOIDS					
Agropyron spicatum	7	6	5	6.0/99	15
Carex pityophila	2	1	2	1.7/99	
Koeleria cristata	3	tr		1.2/67	
Oryzopsis hymenoides	2	tr	tr	1.0/99	
Poa sandbergii	tr		tr	tr/67	2
Carex filifolia		tr		tr/33	
Agropyron smithii		tr		tr/33	
Poa fendleriana					5
FORBS					
Haplopappus acaulis	4	2	2	2.7/99	
Cryptantha flavoculata	tr		tr	tr/67	tr
Erigeron nematophyllus	2	tr	1	1.2/99	
Phlox hoodii	2	2	2	2.0/99	2
Draba oligosperma	1	tr	tr	.7/99	
Arenaria hookeri	tr	1	1	.8/99	
Astragalus spatulatus	tr		tr	tr/67	
Eriogonum sp.	tr	tr	tr	tr/99	
Physaria acutifolia	tr			tr/33	
Senecio werneriifolius	tr	1	1	.8/99	
Petrophytum caespitosum	tr		tr	tr/67	
Descurainia richardsonii	tr			tr/33	3
Hymenoxys acaulis	tr	tr	1	.7/99	
Arenaria fendleri	tr	tr		tr/67	
Machaeranthera grindeloides		1	tr	tr/67	
Erigeron flagellaris		tr		tr/33	
Linum lewisii		tr		tr/33	
Townsendia incana		tr	tr	tr/67	
Lesquerella alpina		tr	tr	tr/67	
Castilleja chromosa		tr	tr	tr/67	
Sedum stenopetalum			tr	tr/33	
Cryptantha gracilis					1
Lappula redowskii					tr
Arabis lignifera					tr
Pteryxia hendersonii					1
Haplopappus armeroides					tr

TABLE 9. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 19 = *Agropyron smithii* Great Basin Grassland, 20 = *Agropyron spicatum–Arenaria hookeri**. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover on the left of the slash and percent constancy on the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	11 N	10 N		10 N	10 N	11 N	11 N	
Range	101W	101W		101W	101W	101W	101W	
Section	S21	S10		S16	S22	S30	S29	
Elevation (meters)	2105	2025		2500	2440	2460	2560	
Aspect	—	—		NW	N	N	SE	
Slope (degrees)	0	0		7	5	15	10	
Soil pH	7.70	7.85	Avg = 7.78	8.05	7.85	7.85	7.85	Avg = 7.90
Soil EC (mmhos/cm)	.31	.32	Avg = .32	.45	.37	.44	.38	Avg = .41
Plant association number	19			20				
Plot number	1	2	Cov/Con	1	2	3	4	Cov/Con
SHRUBS								
Artemisia nova				tr	tr			tr/50
Pediocactus simpsonii				tr				tr/25
Ceratoides lanata					tr			tr/25
Artemisia frigida				tr	2	tr		.8/75
Cercocarpus ledifolius var. *intricatus*							tr	tr/25
GRAMINOIDS								
Agropyron smithii	50	50	50.0/99	tr		tr		tr/50
Bromus tectorum	tr	tr	tr/99					
Sitanion hystrix	tr		tr/50					
Bromus inermis		tr	tr/50					
Agropyron spicatum				6	7	5	6	6.0/99
Koeleria cristata				1	1	1	tr	.9/99
Poa sandbergii						tr	tr	tr/50
Oryzopsis hymenoides						tr		tr/25
FORBS								
Polygonum aviculare	3	tr	1.8/99					
Monolepis nuttalliana	1		tr/50					
Atriplex argentea	1	tr	.8/99					
Plagiobothrys scouleri	1		tr/50					
Cryptantha kelseyana	tr		tr/50					
Descurainia sophia	tr		tr/50					
Conringia orientalis		2	1.0/50					
Descurainia richardsonii		tr	tr/50					
Iva axillaris		10	5.0/50					
Lappula redowskii		tr	tr/50					
Grindelia sp.		tr	tr/50					
Arenaria hookeri				3	4	3	2	3.0/99
Astragalus spatulatus				1	tr	2	1	1.1/99
Lesquerella alpina				4	3	tr	tr	2.0/99
Paronychia sessiliflora				1	tr	2	1	1.1/99
Phlox hoodii				3	5	4	4	4.0/99
Townsendia incana				1	2	1	tr	1.1/99
Draba oligosperma				1	tr	1	tr	.8/99
Hymenoxys acaulis				1	3	5	1	2.5/99
Erigeron sp.				tr	1	1	tr	.8/99
Lomatium orientale				tr	tr			tr/50
Haplopappus acaulis				tr		tr		tr/50
Petrophytum caespitosum				tr	1		2	.9/75
Machaeranthera grindeloides					tr		tr	tr/50
Sedum stenopetalum					tr	tr	tr	tr/75
Cryptantha sericea						tr		tr/25
Senecio werneriifolius						tr	tr	tr/50
Potentilla ovina						tr		tr/25
Cryptantha flavoculata							tr	tr/25
Selaginella densa							tr	tr/25

ridge tops probably blown free of snow in the winter. Similar habitats in the true alpine of the southern Rocky Mountains also have cushion plants of the same genera (*Arenaria, Paronychia, Phlox, Draba*) but different species. To add to the comparison, the upper tree line in the Limestone Ridge area where this association occurs sometimes has a very dwarfed "krummholz" appearance (Fig. 2). Elevations range from 2400 to 2560 m. The association occurs on any aspect but is most often missing on lee slopes with easterly exposure. Soils have an average pH of 7.90 and electrical conductivity of .41 mmhos/cm (Table 9).

The association consists of a very sparse collection of graminoids and "cushion plants," or low-growing forbs. Total cover averages 20%–25%. Rocks and lichens are conspicuous (Fig. 4). The shrub layer is almost nonexistent, though *Artemisia frigida* often occurs in small amounts. *Agropyron spicatum*, with 5%–7% cover, and *Koeleria cristata*, with trace %–1% cover are consistently present. Cushion plants always present, with 1%–5% cover each, include *Arenaria hookeri, Astragalus spatulatus, Draba oligosperma, Hymenoxys acaulis, Lesquerella alpina, Paronychia sessiliflora, Phlox hoodii*, and *Townsendia incana*. There are no clear dominants among this set of species. Relative amounts of each species vary from site to site. *Arenaria hookeri*'s presence distinguishes this association from other *Agropyron spicatum* associations that have been described in the western United States.

The association occurs in the study area only on Limestone Ridge. It very likely also occurs on similar Madison Limestone exposures that occur on the southern part of Douglas Mountain south of the study area, and it may occur in Dinosaur National Monument or in the eastern Uinta Mountains in Utah. Other cushion plant assemblages have been observed in southwestern Wyoming, as well as on the Great Plains (R. Lichvar, personal communication 1982), but it is not known if these are the same association.

21. *Carex aquatilis* Wetland.—This association occurs on the saturated soils alongside streams, creeks, and ponds on alluvial parent materials, generally above 2285 m in elevation in the study area. It often occurs below springs that originate in isolated aspen stands, in an area otherwise dominated by sagebrush. Slopes are variable, ranging from 0°–20°. Soils have an average pH of 7.20, the lowest observed in the study area, and an electrical conductivity of .47 mmhos/cm (Table 10).

The association is very common in the study area, but only two stands could be located that were relatively undisturbed. The description is thus somewhat tentative. *Carex aquatilis* dominates the association (Table 10, Fig. 4), with about 40% cover. *Juncus balticus* and *Eleocharis palustris* are important subdominants, each regularly having 5%–10% cover. *Carex rostrata* or *Equisetum arvense* may have 5%–10% cover in some stands or be absent entirely.

Domestic livestock grazing results in declines in *Carex aquatilis*, which may result in increases in the exotic *Poa pratensis* or in weedy natives, such as *Iris missouriensis*.

The association occurs above about 2285 m in elevation in scattered localities throughout the western two-thirds of Colorado. It also occurs in Oklahoma (Penfound 1953), Wyoming (Knight and Thilenius 1975, Billings and Mooney 1959), Canada (Looman 1982), and in other scattered localities throughout the western United States.

22. *Eleocharis palustris* Wetland.—This association occurs on the bottom of ephemeral ponds or playas at about 1830 m in elevation. The parent material is Quaternary alluvium. Soils have a heavy clay content, an average pH of 7.80, and an electrical conductivity of .76 mmhos/cm (Table 10).

Only one occurrence of this association was located in the study area, but, because the association is well-known elsewhere, it seems appropriate to add data from the study area to the available knowledge. The one occurrence was sampled in two separate areas. *Eleocharis palustris* dominates the association, with 45%–50% cover. Other commonly associated graminoids include *Hordeum jubatum* and *Agropyron smithii*.

Domestic livestock grazing may tend to result in increases in *Hordeum jubatum, Polygonum aviculare*, and *Kochia scoparia*.

The association occurs in the study area at only one location, adjacent to Irish Lakes. It occurs in scattered localities throughout Colorado from 1525 to 2750 m in elevation. It also

TABLE 10. Percent cover and constancy of shrubs and herbs, plot locations, and physical parameters. Plant association numbers correspond to those in the text. 21 = *Carex aquatilis* Wetland, 22 = *Eleocharis palustris* Wetland. Table entries under each plot are percent canopy cover. Tr = trace quantities (less than .5% cover). Table entries under Cov/Con are average percent canopy cover on the left of the slash and percent constancy on the right of the slash. 100 is abbreviated to 99. Soil electrical conductivity (soil EC) is discussed in the text.

Township	12 N	11 N		10 N	10 N	
Range	103W	102W		101W	101W	
Section	S36	S8		S10	S10	
Elevation (meters)	2500	2375		2020	2025	
Aspect	W	E		—	—	
Slope (degrees)	4	8		0	0	
Soil pH	7.70	6.70	Avg = 7.20	7.75	7.85	Avg = 7.80
Soil EC (mmhos/cm)	.37	.56	Avg = .47	.51	1.01	Avg = .76
Plant association number		21			22	
Plot number	1	2	Cov/Con	1	2	Cov/Con
SHRUBS						
Salix bebbiana	tr		tr/50			
Potentilla fruticosa	tr		tr/50			
GRAMINOIDS						
Carex aquatilis	40	40	40.0/99			
Juncus balticus	10	5	7.5/99			
Eleocharis palustris	5	4	4.5/99	50	45	47.5/99
Deschampsia cespitosa	1	1	1.0/99			
Equisetum arvense	7		3.5/50			
Carex aurea	tr		tr/50			
Poa pratensis	tr	3	1.8/99			
Carex rostrata		10	5.0/50			
Carex microptera		3	1.5/50			
Muhlenbergia filiformis		tr	tr/50			
Sitanion hystrix				tr		tr/50
Hordeum jubatum				1	5	3.0/99
Agropyron smithii				1	1	1.0/99
Bromus tectorum					tr	tr/50
FORBS						
Dodecatheon pulchellum	2		1.0/50			
Viola nephrophylla	3		1.5/50			
Taraxacum officinale	1	tr	.8/50			
Trifolium longipes	tr	tr	tr/99			
Cirsium arvense	tr		tr/50			
Antennaria microphylla	tr		tr/50			
Erigeron sp.	2		1.0/50			
Sisyrinchium idahoense var. *occidentale*	tr		tr/50			
Epilobium ciliatum	tr		tr/50			
Iris missouriensis	tr		tr/50			
Ranunculus cymbalaria		2	1.0/50			
Veronica americana		tr	tr/50			
Rorippa sinuata				5	3	4.0/99
Polygonum aviculare				2	1	1.5/99
Grindelia sp.				tr		tr/50
Rumex salicifolius				1	tr	.8/99
Atriplex argentea				1	1	1.0/99
Sesuvium verrucosum					tr	tr/50
Chenopodium glaucum					2	1.0/50
Kochia scoparia					tr	tr/50
Sisymbrium altissimum					tr	tr/50

occurs from Nevada (Billings 1945) to Oklahoma (Penfound 1953).

Other Vegetation Types Not Sampled

A single stand was located (T10N R101W S9 SE4) that appears to represent the *Juniperus osteosperma–Pinus edulis/Purshia tridentata/Poa fendleriana* association, which is common in southwestern Colorado in the Mesa Verde region (Baker 1984), though the stand would be very disjunct and may simply represent an anomaly.

A single stand of what appears to have been a *Juniperus osteosperma–Pinus edulis/Cercocarpus montanus/Agropyron spicatum* association was located on the northwestern lower slopes of Limestone Ridge. Fragments of this association were observed in other areas, but they were either insufficiently large or too disturbed to be sampled. A stand similar to this was also observed in Dinosaur National Monument in 1983 (S. Wathen, personal communication 1983).

An area in T11N R101W S29 SE4 contains an open apparently wind-trimmed stand of prostrate *Juniperus osteosperma* (Fig. 2). The authors know of no other reports of "krummholz" growth form in pinyon-juniper woodlands. This stand does occur near the upper tree limit on Limestone Ridge, but other upper tree limit areas in the vicinity lack this phenomenon.

Several small stands of the *Artemisia tridentata* ssp. *wyomingensis–Symphoricarpos oreophilus/Elymus cinereus* association described by Baker (1982b, 1983) were observed along the north end of Vermillion Bluffs, but none were sufficiently undisturbed to be usable for sampling.

Several stands of *Sarcobatus vermiculatus* were observed in the study area. Without exception, they contain understories dominated by annual exotic weeds (e.g., *Bromus tectorum, Chorispora tenella, Malcomia africana, Halogeton glomeratus*). It is likely that prior to livestock grazing the understory of these stands was dominated by the native perennial grass *Distichlis spicata* var. *stricta*.

Occurring on dry lakebeds (e.g., Fonce Lake) are large, nearly monospecific stands of *Iva axillaris*. It is not known at this time if such stands occurred as a natural part of the presettlement vegetation spectrum.

Distribution of the Plant Associations in the Study Area

From an examination of the soils data presented in Tables 1–10, it is clear that soil pH and electrical conductivity are not sufficiently different among the plant associations to fully explain their environmental differences. It is likely that additional data on soil chemical and physical properties would help clarify the differences among associations, but collection of those data was beyond the scope of this study. Instead, the general arrangement of the plant associations in the landscape can be clarified in most cases by simple reference to topographic setting, aspect, and parent material. The arrangement of plant associations differs between the three geographic subdivisions of the study area.

In the Uinta Mountains section of the study area below 2375 m northerly facing slopes on calcareous substrata have the *Artemisia nova/Agropyron spicatum* association, whereas similar flat areas have the *Artemisia nova/Stipa comata* association. Southerly facing calcareous slopes may have the *Juniperus osteosperma–Pinus edulis/Artemisia nova/Agropyron spicatum* association, and rocky slopes on sandstones have the *Juniperus osteosperma/Agropyron spicatum* association. Very rocky sandstone ridges have the *Juniperus osteosperma–Pinus edulis/Cercocarpus ledifolius* var. *intricatus* association. Low-elevation rolling areas or flats that are noncalcareous have the *Artemisia tridentata* ssp. *wyomingensis/Agropyron smithii* association, whereas finer-textured soils have the *Agropyron smithii* Great Basin Grassland. In the northern part of the Uinta Mountains area, *Cercocarpus montanus/Agropyron spicatum* occurs on northerly facing noncalcareous substrata. Low-elevation ephemeral ponds and playas have the *Eleocharis palustris* Wetland association. Above 2375 m *Artemisia nova/Agropyron spicatum* occurs on calcareous slopes, and the *Cercocarpus ledifolius* var. *intricatus/Agropyron spicatum* association occurs on rocky calcareous ridge tops, with the *Agropyron spicatum–Arenaria hookeri** association occupying similar but more wind-exposed sites. The *Cercocarpus ledifolius/Artemisia tridentata* ssp. *wyomingensis–Symphoricar-pos oreophilus/Agropyron spicatum* association occurs in bands on slopes or

in slight draws. The *Carex aquatilis* Wetland occupies areas below springs and along creeks. There are also forested areas dominated by *Populus tremuloides*, *Pinus contorta*, and *Pseudotsuga menziesii*. These upper-elevation forests were not sampled during this study.

In the Washakie Basin part of the study area, the rolling plateaus along Vermillion and Dry creeks below 2375 m contain an alternating mosaic of two associations, the *Artemisia tridentata* ssp. *wyomingensis/Agropyron smithii* association on coarser-textured, less saline soils, often on slightly convex sites, and the *Atriplex gardneri/Oryzopsis hymenoides* association on finer-textured, more saline soils, often on slightly concave sites. On more dissected sloping uplands, the *Atriplex confertifolia/Agropyron spicatum* association occurs on benches and ridges, whereas the *Atriplex confertifolia/Elymus salina* association occupies steep, rocky, northerly facing slopes. Above 2375 m the *Artemisia tridentata* ssp. *wyomingensis/Agropyron spicatum* association occurs on flat to gently sloping plateaus or as openings in *Juniperus osteosperma/Agropyron spicatum* woodlands. *Artemisia tridentata* ssp. *vaseyana/Agropyron spicatum* occupies windy sites on shallow soils on ridge tops in a few areas along Vermillion Bluffs. The *Atriplex confertifolia/Stipa comata* association occurs on flat to gently rolling uplands in the Powder Wash area. Further south on the southern end of Sevenmile Ridge, the *Atriplex gardneri/Elymus salina* association occurs on flat ridges on soils with a high clay content.

Browns Park contains a large area of the *Artemisia tridentata* ssp. *wyomingensis–Atriplex confertifolia–Grayia spinosa*/Stipa comata* association. A few north-facing slopes have the *Artemisia nova/Agropyron spicatum* association.

Status of the Plant Associations

Seven (numbers 4, 11, 12, 14, 16, 17, and 20) of the 22 plant associations described here are not known from outside the study area, based on currently available data. Three of these (4, 17, and 20) are restricted to Madison Limestone. The Madison Limestone occurs in adjoining Utah in the Uinta Mountains, but the vegetation of that area is currently largely undescribed. The other restricted associations occur on Browns Park, Green River, or Wasatch formations. These geologic strata and similar topographic situations occur in adjacent Utah and Wyoming, and it is likely that, as the vegetation of these adjoining regions becomes better known, the ranges of some of these associations will be expanded; but it is possible that this may not be so. On the basis of current knowledge, the study area has about as high a percentage of "endemic" plant associations as the Piceance Basin (Baker 1982b), the other major area of Green River Fm. exposures in Colorado. As in that area, the more extreme environments and uncommon geologic strata in the study area contain plant associations with restricted ranges, whereas mesic situations, northerly facing slopes, and sandstones have more wide-ranging associations. Many of these wider-ranging associations in the study area extend across part or all of the northern Great Basin.

Only a very small percentage of the study area still contains vegetation that retains to a substantial degree the composition and structure it had prior to the introduction of domestic livestock grazing and other recent land uses. Although records such as these of that presettlement composition and structure offer a permanent record valuable for rehabilitation and reclamation, it is of vital importance to the future understanding of the functioning of these ecosystems that the few extant remnants be perpetuated for additional research.

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LITERATURE CITED

ANDERSON, D. C., K. T. HARPER, AND R. C. HOLMGREN. 1982a. Factors influencing development of cryptogamic soil crusts in Utah deserts. J. Range Mgmt. 35(2): 180–184.

ANDERSON, D. C., K. T. HARPER, AND S. R. RUSHFORTH. 1982b. Recovery of cryptogamic soil crusts from grazing on Utah winter ranges. J. Range Mgmt. 35(3):355–359.

BAKER, W. L. 1982a. Vegetation description in Colorado—where are the gaps? J. Colo.-Wyom. Acad. Sci. 14(1):39 (Abstract).

———. 1982b. Natural vegetation of the Piceance Basin, Colorado. App. D, Pages 1–113 *in* J. S. Peterson, and W. L. Baker, eds., Inventory of the Piceance Basin, Colorado: threatened and endangered plants, plant associations, and the general flora. Unpublished report prepared for the Craig District Office, Bureau of Land Management, Craig, Colorado, by Colorado Natural Heritage Inventory, Denver.

———. 1983. Some aspects of the presettlement vegetation of the Piceance Basin, Colorado. Great Basin Nat. 43(4):687–699.

———. 1984. A preliminary classification of the natural vegetation of Colorado. Great Basin Nat. 44(4):647–676.

BARBOUR, M. G., AND J. MAJOR, eds. 1977. Terrestrial vegetation of California. John Wiley and Sons, New York. 1002 pp.

BARKWORTH, M. E., AND R. J. ATKINS. 1984. *Leymus* Hochst. (Gramineae: Triticeae) in North America: taxonomy and distribution. Amer. J. Bot. 71:609–625.

BEETLE, A. A. 1961. Range survey in Teton County, Wyoming. Part 1. Ecology of range resources. Univ. of Wyom., Agric. Expt. Sta. Bull. 376. 38 pp.

BILLINGS, W. D. 1945. The plant associations of the Carson Desert region, western Nevada. Butler Univ. Bot. Studies 7:89–123.

BILLINGS, W. D., AND H. A. MOONEY. 1959. An apparent frost hummock–sorted polygon cycle in the alpine tundra of Wyoming. Ecology 40:16–20.

BLACKBURN, W. H., R. E. ECKERT, JR., AND P. T. TUELLER. 1969a. Vegetation and soils of the Cow Creek watershed. Coll. Agric., Univ. of Nev. Bull. R49. 77 pp.

———. 1969b. Vegetation and soils of the Coils Creek watershed. Coll. Agric., Univ. of Nev. Bull. R48. 82 pp.

———. 1969c. Vegetation and soils of the Crane Springs watershed. Coll. Agric., Univ. of Nev. Bull. R55. 63 pp.

———. 1971. Vegetation and soils of the Rock Springs watershed. Coll. Agric., Univ. of Nev. Bull. R83. 115 pp.

BRADLEY, W. H. 1964. Geology of Green River Formation and associated Eocene rocks in southwestern Wyoming and adjacent parts of Colorado and Utah. USGS Prof. Paper 496–A. 86 pp.

CHRISTENSEN, E. M., AND H. B. JOHNSON. 1964. Presettlement vegetation and vegetational change in three valleys in central Utah. Brigham Young Univ. Sci. Bull., Biol. Ser. 4(4):1–16.

CHRISTENSEN, E. M., AND S. L. WELSH. 1963. Presettlement vegetation of the valleys of western Summit and Wasatch counties, Utah. Proc. Utah Acad. Sci. 40:163–174.

DAUBENMIRE, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monogr. 22:301–330.

———. 1970. Steppe vegetation of Washington. Washington Agric. Expt. Sta. Tech. Bull. No. 62. 131 pp.

DESPAIN, D. 1973. Vegetation of the Bighorn Mountains, Wyoming, in relation to substrate and climate. Ecol. Monogr. 43:329–355.

DIXON, H. 1935. Ecological studies on the high plateaus of Utah. Bot. Gaz. 97:272–320.

DONART, G. B., D. SYLVESTER, AND W. HICKEY. 1978. A vegetation classification system for New Mexico, USA. Pages 488–490 *in* D. N. Hyder, ed., Proc. 1st Intern. Rangeland Congr., Denver, Colorado, 14–18 August 1978, Soc. Range Mgmt., Denver.

GALE RESEARCH COMPANY. 1980. Page 104 *in* Climates of the states: Colorado. Gale Res. Co., Book Tower, Detroit, Michigan. 2d ed.

GRAHAM, E. H. 1937. Botanical studies in the Uinta Basin of Utah and Colorado. Ann. Carnegie Museum 26:1–432.

HESS, K. 1981. Phyto-edaphic study of habitat types of the Arapaho-Roosevelt National Forest, Colorado. Unpublished dissertation. Colorado State University, Fort Collins. 558 pp.

HIRONAKA, M. 1978. Basic synecological relationships of the Columbia River sagebrush type. Pages 27–32 *in* The Sagebrush Ecosystem: a symposium. Utah State University, College of Natur. Resources, Logan, Utah.

JOHNSON, J. L., AND R. D. PFISTER. 1982. A survey of potential ecological natural landmarks of the middle Rocky Mountains. Unpublished report prepared for the National Park Service by the Intermountain Forest and Range Experiment Station, Ogden, Utah. 197 pp.

KARTESZ, J. T. AND R. KARTESZ. 1980. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. University of North Carolina Press, Chapel Hill. 498 pp.

KNIGHT, D. H., AND J. THILENIUS. 1975. Vegetation ecology. Pages 37–59, 99–104 *in* D. H. Knight et al., eds. The Medicine Bow Ecology Project: the potential sensitivity of various ecosystem components to winter precipitation management in the Medicine Bow Mountains, Wyoming. Report to the Office of Atmos. Water Res., Bur. of Reclamation, by the University of Wyoming, Laramie.

LINDAUER, I. E., C. E. OLMSTED III, W. A. KELLEY, AND W. F. GREY. 1982. Terrestrial ecosystems of northwest Colorado: an annotated bibliography and vegetation classification. Unpublished report prepared for the State Office, Bureau of Land Management, by the University of Northern Colorado, Greeley. 123 pp.

LOOMAN, J. 1982. The vegetation of the Canadian prairie provinces. III. Aquatic and semi-aquatic vegetation, Part 2: Freshwater marshes and bogs. Phytocoenologia. 10(4):401–423.

Miller, R. F., F. A. Branson, I. S. McQueen, and C. T. Snyder. 1982. Water relations in soils as related to plant communities in Ruby Valley, Nevada. J. Range Mgmt. 35:462–468.

Mueggler, W. F., and W. L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. USDA For. Serv. Gen. Tech. Rep. INT-66, Intermt. For. and Range Expt. Sta., Ogden, Utah. 154 pp.

Nichol, A. A. 1937. The natural vegetation of Arizona. University of Arizona, Agric. Expt. Sta. Tech. Bull. 68:177–222.

Nightingale, W. T. 1930. Geology of Vermillion Creek gas area in southwest Wyoming and northwest Colorado. Amer. Assoc. Petrol. Geol. Bull. 14:1013–1040.

Pammel, L. H. 1903. Some ecological notes on the vegetation of the Uintah Mountains. Proc. Iowa Acad. Sci. 10:57–68.

Passey, H. B., V. K. Hugie, E. W. Williams, and D. E. Ball. 1982. Relationships between soil, plant community, and climate on rangelands of the Intermountain West. USDA Soil Cons. Serv. Tech. Bull. 1669. 123 pp.

Penfound, W. T. 1953. Plant communities of Oklahoma lakes. Ecology 34:561–583.

Peterson, J. S., and W. L. Baker. 1983. Inventory of selected areas in Colorado. Unpublished report to the Colorado Natural Areas Prog., Dept. of Nat. Resources, State of Colorado, by Colorado Natural Heritage Inventory, Denver.

Pfister, R. D. 1982. Designing succession models to meet management needs. Pages 44–53 *in* J. E. Means, ed., Forest succession and stand development research in the northwest. Proceedings of the symposium held 26 March 1981 at Corvallis, Oregon. Forest Research Laboratory, Oregon State University, Corvallis.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. USDA For. Serv. Gen. Tech. Rep. INT–34, Intermt. For. and Range Expt. Sta., Ogden, Utah. 174 pp.

Richards, L. A., ed. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook 60. 160 pp.

Rowley, P. D., O. Tweto, W. R. Hansen, and P. E. Carrara. 1979. Geologic map of the Vernal 1 degree × 2 degree quadrangle, Colorado, Utah, and Wyoming. USGS Misc. Field Studies Map MF–1163.

Sears, J. D. 1924. Geology and oil and gas prospects of part of Moffat County, Colorado, and southern Sweetwater County, Wyoming. USGS Bull. 751–G.

Sharp, L. A., and K. D. Sanders. 1978. Rangeland resources of Idaho. University of Idaho Wildl. and Range Expt. Sta. Contr. 141. 74 pp.

Smith, E. L., Jr. 1966. Soil-vegetation relationships of some *Artemisia* types in North Park, Colorado. Unpublished dissertation, Colorado State University Fort Collins.

Soltanpour, P. N., and S. M. Workman. 1981. Soil-testing methods used at Colorado State University Soil Testing Laboratory for the evaluation of fertility, salinity, sodicity, and trace element toxicity. Colorado State Univ. Expt. Sta. Tech. Bull. 142. 22 pp.

Svihla, R. D. 1932. The ecological distribution of the mammals on the north slope of the Uinta Mountains. Ecol. Monogr. 2:47–73.

Terwilliger, C., Jr., and J. A. Tiedeman. 1978. Habitat types of the mule deer critical winter range and adjacent steppe region of Middle Park, Colorado. Unpublished report on file at Rocky Mt. For. and Range Expt. Sta., Fort Collins, Colorado. 108 pp.

Thatcher, A. P. 1959. Distribution of sagebrush as related to site differences in Albany County, Wyoming. J. Range Mgmt. 12:55–61.

Tweit, S. J., and K. E. Houston. 1980. Grassland and shrubland habitat types of the Shoshone National Forest. Unpublished report on file at the Shoshone National Forest Headquarters. 143 pp.

Vale, T. R. 1982. Plants and people: vegetation change in North America. Assoc. Amer. Geogr., Resource Publ. in Geogr., Washington, D.C. 88 pp.

Welsh, S. L. 1957. An ecological survey of the vegetation of the Dinosaur National Monument, Utah. Unpublished thesis. Brigham Young University, Provo, Utah.

Wight, J. R., and H. G. Fisser. 1968. *Juniperus osteosperma* in northwestern Wyoming, their distribution and ecology. University of Wyoming, Agric. Expt. Sta., Science Monogr. 7. 31 pp.

Woodbury, A. M., S. D. Durrant, and S. Flowers. 1960. A survey of vegetation in the Flaming Gorge Reservoir Basin. Dept. of Anthropology, University of Utah, Anthropol. Papers 45. 121 pp.

Young, J. A., R. A. Evans, and P. T. Tueller. 1975. Great Basin plant communities—pristine and grazed. Pages 187–215 *in* R. Elston, and P. Headrick, eds., Holocene environmental change in the Great Basin. Nevada Archeol. Surv. Res. Paper 6.

Zamora, B., and P. T. Tueller. 1973. *Artemisia arbuscula*, *A. longiloba*, and *A. nova* habitat types in northern Nevada. Great Basin Nat. 33:225–242.